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Annual Progress Report

North Central Regional Aquaculture Center

Annual Progress Report

Disciplines
Agriculture | Aquaculture and Fisheries

NORTH CENTRAL
REGIONAL AQUACULTURE CENTER

ANNUAL PROGRESS REPORT 2002-03

JANUARY 2004

ANNUAL PROGRESS REPORT

For the Period
September 1, 2002 to August 31, 2003

January 2004

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A table of commonly used abbreviations and acronyms can be found inside the back cover.

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INTRODUCTION

The U.S. aquaculture industry is an important sector of U.S. agriculture. Production in 2001 was about 819 million pounds and generated approximately $935 million for producers. Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood has been met by imports. The value of imported fisheries products has substantially increased over the last two decades. In 2002, the U.S. imported $19.7 billion of fisheries products and the trade deficit was $8.0 billion for all fisheries products, most of which was for edible fish and shellfish.

Landings for most commercial capture fisheries species and recreational fisheries of the United States have been relatively stable during the last decade, with many fish stocks being over exploited. In this situation, aquaculture provides an opportunity to reduce the trade deficit and meet the rising U.S. demand for fish products. A strong domestic aquaculture industry is needed to increase U.S. production of fish and shellfish. This can be achieved by a partnership among the Federal Government, State and local public institutions, and the private sector with expertise in aquaculture development.

Congress recognized the opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act (P.L. 96-362). Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) in Title XIV of the Agriculture and Food Act of 1981 (P.L. 97-98) by granting authority to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, western, and tropical/subtropical Pacific regions of the country. The Farm Security and Rural Investment Act of 2002 (P.L. 107-171), otherwise known as the Farm Bill, has reauthorized the Regional Aquaculture Center program at $7.5 million per annum. As used here, a center refers to an administrative center. Centers do not provide monies for brick-and-mortar development. Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by the U.S. Department of Agriculture (USDA) and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

The mission of the Regional Aquaculture Centers (RACs) is to support aquaculture research, development, demonstration, and extension education to enhance viable and profitable U.S. aquaculture production which will benefit consumers, producers, service industries, and the American economy.

The North Central Regional Aquaculture Center (NCRAC) was established in February 1988. It serves as a focal point to assess needs, establish priorities, and implement research and extension educational programs in the twelve state agricultural heartland of the United States which includes Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. NCRAC also provides coordination of interregional and national programs through the National Coordinating Council for Aquaculture (NCC). The council is composed of the RAC directors and USDA aquaculture personnel.

ORGANIZATIONAL STRUCTURE

Michigan State University (MSU) and Iowa State University (ISU) work together to develop and administer programs of NCRAC through a memorandum of understanding. MSU is the prime contractor for the Center and has administrative responsibilities for its operation. The Director of NCRAC is located at MSU. ISU shares in leadership of the Center through an office of the Associate Director who is responsible for all aspects of the Center's publications, technology transfer, and outreach activities.

At the present time the staff of NCRAC at MSU includes Ted R. Batterson, Director, and Liz Bartels, Executive Secretary. The Center Director has the following responsibilities:

- Developing and submitting proposals to USDA Cooperative State Research, Education and Extension Service (USDA/CSREES) which, upon approval, becomes a grant to the Center;
- Developing appropriate agreements (sub-contracts) with other parties, including ISU for the Associate Director’s office, for purposes of transferring funds for implementation of all projects approved under the grants;
- Serving as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serving as an ex-officio (non-voting) member of the Technical Committee and Industry Advisory Council;
- Coordinating the development of research and extension plans, budgets, and proposals;
- Coordinating and facilitating interactions among the Administrative Center, Board of Directors, Industry Advisory Council, and Technical Committee;
- Monitoring research and extension activities;
- Arranging for review of proposals for technical and scientific merit, feasibility, and applicability to priority problems and preparing summary budgets and reports as required;
- Recruiting other Administrative Center staff as authorized by the Board of Directors;
- Maintaining liaison with other RACs; and
- Serving on the NCC.

At the present time NCRAC's Office for Publications and Extension Programs at ISU is under the direction of Joseph E. Morris, Associate Director. The Associate Director has the following responsibilities:

- Coordinating, facilitating, and executing regional aquaculture extension program activities;
- Serving as head of Publications for NCRAC, including editor of the fact sheet, technical bulletin, culture manual, and video series as well as of the NCRAC Newsletter;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA Regional Aquaculture Centers; and
- Serving as a member of NCRAC's Extension Executive Committee.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of four persons from the IAC, a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university, representatives from the two universities responsible for the center: Michigan State and Iowa State, and chairs of the two subcommittees of the Center's Technical Committee. The IAC is composed of representatives from each state's aquaculture association and six at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a sub-committee for Research (TC/R). Directors of the Cooperative Extension Service within the North Central Region appoint representatives to the TC/E. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. Each sub-committee of the TC has a chairperson who serves as a member of the BOD.

NCRAC functions in accordance with its *Operations Manual* which is periodically amended and updated with BOD approval. It is an evolving document that has changed as the Center's history lengthens. It is used for the development of the cooperative regional aquaculture and extension projects that NCRAC funds.

ADMINISTRATIVE OPERATIONS

Since inception of NCRAC February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the BOD, IAC, TC, and project work groups for the North Central Region as well as representing the region on the NCC. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication among all components of the Center and the aquaculture community.

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSREES/Grants Management Branch for approval. To date the Center has received 16 grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY90 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500-6916), FY93 (Grant #93-38500-8392), FY94 (Grant #94-38500-0048), FY95 (Grant #95-38500-1410), FY96 (Grant #96-38500-2631), FY97 (#97-38500-3957), FY98 (#98-38500-5863), FY99 (#99-38500-7376), FY00 (#00-38500-8984), FY2001 (#2001-38500-10369), FY2002 (#2002-38500-11752), and FY2003 (#2003-38500-12995) with monies totaling $11,783,909. Currently, five grants are active (FY99-03); the first eleven grants (FY88-98) have terminated.
- The Center annually coordinates a program planning meeting which typically sets priorities for the next funding cycle and calls for development of project outlines to address priority problem areas.
- Work Groups are formed which submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region and a Project Review Committee.
- The BOD, using the Project Review Committee's recommendation and reviewers' responses, decides which projects are to be approved and funding levels. The Center conveys BOD decisions to all Project Work Groups. Those that are approved for funding are

asked to submit revised project outlines incorporating BOD, Project Review Committee, and reviewers' comments.

- The Center then submits the revised project outlines as a Plan of Work (POW) to USDA for approval.
- Once a POW is approved by USDA, the Center then prepares subcontracts for each participating institution. The Center receives all invoices for subcontractual agreements and prepares payment vouchers for reimbursement. Thus, the Center staff serve as fiscal agents for both receiving and disbursing funds in accordance with all terms and provisions of the grants.

Through August 31, 2003, the Center has funded or is funding 62 projects through 322 subcontracts from the first 15 grants received. Funding for these Center supported projects is summarized in Table 1 below (pages 5-6). Information about funded projects is also available at the Center's Web site (http://ag.ansc.purdue.edu/aquanic/ncrac).

During this reporting period, the Publications Office at ISU produced and distributed a number of publications including fact sheets, technical bulletins, videos, and the Center's newsletter. A complete list of all publications from this office is included in the Appendix under Extension.

Other areas of support by the Administrative Office during this reporting period included: monitoring research and extension activities and developing progress reports; developing liaisons with appropriate institutions, agencies and clientele groups; soliciting, in coordination with the other RACs, written testimony for the U.S. House Appropriations Subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies and the U.S. Senate Appropriations Subcommittee on Agriculture, Rural Development, and Related Agencies; participating in the NCC; numerous oral and written presentations to both professional and lay audiences; working with other fisheries and aquaculture programs throughout the North Central Region; and in conjunction with the Aquaculture Network Information Center (AquaNIC) maintaining the NCRAC Web site.

PROJECT REPORTING

As indicated in Table 1, NCRAC has funded a number of projects for many of the project areas it has selected for research and extension activities. For example, there have been eight separately funded projects in regard to Extension and Yellow Perch. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are continuations of previously funded activities while at other times they are addressing new objectives. Presented below are Progress or Termination Reports mostly for projects that were underway or completed during the period September 1, 2002 to August 31, 2003. Projects, or Project components, that terminated prior to September 1, 2002 have been reported on in earlier documents (e.g., 1989-1996 Compendium Report and other Annual Progress Reports).

A cumulative list of all publications, manuscripts, papers presented, or other outputs for all funded NCRAC project areas is contained in the Appendix.

Table 1. North Central Regional Aquaculture Center funded projects.

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
Extension	1	5/1/89-4/30/91	$39,221	88-38500-3885
			$37,089	89-38500-4319
	2	3/17/90-8/31/91	$31,300	89-38500-4319
	3	9/1/91-8/31/93	$94,109	91-38500-5900
	4	9/1/93-8/31/95	$110,129	91-38500-5900
	5	9/1/95-8/31/97	$10,813	92-38500-6916
			$20,391	95-38500-1410
	6	9/1/97-8/31/99	$38,000	97-38500-3957
	7	9/1/99-8/31/01	$94,000	99-38500-7376
	8	9/1/01-8/31/03	$28,500	99-38500-7376
			$18,000	2001-38500-10369
			$521,552	
Economics/Marketing	1	5/1/89-12/31/91	$127,338	88-38500-3885
			$34,350	89-38500-4319
	2	9/1/91-8/31/92	$53,300	91-38500-5900
	3	9/1/93-8/31/95	$40,000	93-38500-8392
	4	9/1/99-8/31/01	$47,916	97-38500-3957
			$302,904	
Yellow Perch	1	5/1/89-8/31/91	$76,957	88-38500-3885
			$85,723	89-38500-4319
	2	6/1/90-8/31/92	$92,108	90-38500-5008
	3	9/1/91-8/31/93	$99,997	91-38500-5900
	4	9/1/93-8/31/95	$150,000	93-38500-8392
	5	9/1/95-8/31/97	$199,507	95-38500-1410
	6	9/1/97-8/31/99	$185,458	97-38500-3957
	7	9/1/98-8/31/00	$92,370	98-38500-5863
	8	9/1/01-5/31/04	$326,730	00-38500-8984
			$125,016	2001-38500-10369
			$1,433,866	
Hybrid Striped Bass	1	5/1/89-8/31/91	$68,296	88-38500-3885
			$68,114	89-38500-4319
	2	6/1/90-8/31/92	$101,000	90-38500-5008
	3	9/1/91-8/31/93	$96,550	91-38500-5900
	4	9/1/93-8/31/95	$168,000	93-38500-8392
	5	9/1/95-8/31/97	$150,000	95-38500-1410
	6	6/1/99-5/31/00	$15,000	96-38500-2631
	7	9/1/01-5/31/04	$98,043	98-38500-5863
			$211,957	2001-38500-10369
			$976,960	
Walleye	1	5/1/89-8/31/91	$177,517	89-38500-4319
	2	6/1/90-8/31/92	$111,657	90-38500-5008
	3	9/1/91-8/31/92	$109,223	91-38500-5900
	4	9/1/92-8/31/93	$75,000	89-38500-4319
	5	9/1/93-8/31/95	$150,000	93-38500-8392
	6	9/1/95-8/31/97	$117,395	94-38500-0048
			$59,835	95-38500-1410
	7	9/1/99-6/30/02	$127,000	98-38500-5863
			$927,627	

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
Sunfish	1	6/1/90-8/31/92	$130,758	90-38500-5008
	2	9/1/92-8/31/94	$149,799	92-38500-6916
	3	9/1/94-8/31/96	$173,562	94-38500-0048
	4	9/1/96-9/31/98	$199,921	96-38500-2631
	5	9/1/99-8/31/01	$199,748	99-38500-7376
			$853,788	
Salmonids	1	6/1/90-8/31/92	$9,000	89-38500-4319
			$120,799	90-38500-5008
	2	9/1/92-8/31/94	$149,997	92-38500-6916
	3	9/1/94-8/31/96	$199,290	94-38500-0048
	4	9/1/97-8/31/99	$158,656	97-38500-3957
			$637,742	
NCR Aquaculture Conference	1	6/1/90-3/31/91	$7,000	90-38500-5008
	2	12/9/98-6/30/99	$3,000	96-38500-2631
			$10,000	
National Aquaculture Extension Workshop/Conference	1	10/1/91-9/30/92	$3,005	89-38500-4319
	2	12/1/96-11/30/97	$3,700	95-38500-1410
	3	11/1/02-10/31/03	$4,500	00-38500-8984
			$11,205	
Crayfish	1	9/1/92-8/31/94	$49,677	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$61,973	92-38500-6916
Wastes/Effluents	1	9/1/92-8/31/94	$153,300	92-38500-6916
	2	9/1/96-8/31/98	$100,000	96-38500-2631
	3	9/1/01-8/31/04	$106,186	00-38500-8984
			$88,814	2001-38500-10369
			$448,300	
National Aquaculture INAD/NADA Coordinator	1	9/1/93-8/31/94	$2,000	89-38500-4319
		5/15/95-5/14/96	$5,000	94-38500-0048
		5/15/96-5/14/97	$6,669	92-38500-6916
			$3,331	95-38500-1410
		5/15/97-5/14/98	$15,000	96-38500-2631
		5/15/98-5/14/99	$13,241	94-38500-0048
		5/15/99-5/14/00	$10,000	95-38500-1410
			$55,241	
Tilapia	1	9/1/96-8/31/98	$118,791	96-38500-2631
	2	9/1/98-5/14/00	$150,000	98-38500-5863
			$268,791	
Aquaculture Drugs	1	7/1/96-6/30/97	$27,000	95-38500-1410
	2	12/1/96-11/30/97	$950	95-38500-1410
	3	10/1/99-9/30/00	$8,415	97-38500-3957
			$36,365	
White Papers	1	7/1/98-12/31/98	$4,999	96-38500-2631
	2	9/1/99-12/31/99	$17,495	97-38500-3957
			$22,494	
Percis III	1	11/1/02-12/31/03	$4,000	00-38500-8984
			$4,000	

PROJECT TERMINATION
OR
PROGRESS REPORTS

EXTENSION[1]

Progress Report for the Period
May 1, 1989 to August 31, 2003

NCRAC FUNDING LEVEL: $521,552 (May 1, 1989 to August 31, 2003)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James M. Ebeling	Ohio State University	Ohio
Robert D. Espeseth	University of Illinois	Illinois
Donald L. Garling	Michigan State University	Michigan
Jeffrey L. Gunderson	University of Minnesota-Duluth	Minnesota
F. Robert Henderson	Kansas State University	Kansas
Chester L. Hill	North Dakota State University	North Dakota
John N. Hochheimer	Ohio State University	Ohio
Paul B. Jarvis	North Dakota State University	North Dakota
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
David L. Klinkebiel	North Dakota State University	North Dakota
Ronald E. Kinnunen	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
David J. Landkamer	University of Minnesota	Minnesota
Charles D. Lee	Kansas State University	Kansas
Frank R. Lichtkoppler	Ohio State University	Ohio
Terry A. Messmer	North Dakota State University	North Dakota
Jeff Mittlemark	University of Minnesota	Minnesota
Joseph E. Morris	Iowa State University	Iowa
Kenneth E. Neils	Kansas State University	Kansas
Robert A. Pierce II	University of Missouri	Missouri
Shawn H. Sanders	North Dakota State University	North Dakota
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
John P. Slusher	University of Missouri	Missouri
Fred L. Snyder	Ohio State University	Ohio
Brian R. Stange	North Dakota State University	North Dakota
LaDon Swann	Purdue University	Indiana/Illinois
Laura G.Tiu	Ohio State University	Ohio

PROJECT OBJECTIVES

(1) Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) Research and Extension Work Groups.

[1]NCRAC has funded eight Extension projects. The first three were chaired by Donald L. Garling, the fourth project was chaired by Fred P. Binkowski and projects 5-8 chaired by Joseph E. Morris. A Project Component Termination Report for one of the objectives of the fifth Extension project is contained in the 1997-98 Annual Progress Report. The eighth project is a 2-year project that began September 1, 2001.

(2) Enhance the NCRAC extension network for aquaculture information transfer.

(3) Provide in-service training for Cooperative Extension Service, Sea Grant Advisory Service, and other landowner assistance personnel.

(4) Develop and implement aquaculture educational programs for the North Central Region (NCR).

(5) Develop aquaculture materials for the NCR including extension fact sheets, bulletins, manuals/guides, and instructional video tapes.

ANTICIPATED BENEFITS

Members of the NCRAC Extension Work Group have promoted and advanced commercial aquaculture in a responsible fashion through an organized education/training outreach program. The primary benefits are:

- Increased public awareness through publications, short courses, and conferences regarding the potential of aquaculture as a viable agricultural enterprise in the NCR;
- Technology transfer to enhance current and future production methodologies for selected species, e.g., walleye, hybrid striped bass, yellow perch, salmonids, and sunfish through hands-on workshops and field demonstration projects;
- Improved lines of communication between interstate aquaculture extension specialists and associated industry contacts;
- Access to information by the aquaculture industry through 24-hour access to worldwide aquaculture information (i.e., photographs, slide sets, and publications); and
- An enhanced legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Aquaculture Extension Work Group members have:

- Served as extension liaison, if not an active researcher, for every NCRAC-funded project.
- Assisted in developing, writing, and editing several culture manuals, e.g., Walleye Culture Manual, Sunfish Culture Guide, and Yellow Perch Culture Manual.
- Assisted with the planning, promotion, and implementation of taxa-specific workshops held throughout the region as well as other conferences and symposia.
- Provided the NCRAC Economics and Marketing Work Group with information relevant to that group's efforts to develop production budgets and expected revenues for the commercial production of food fish.
- Participated as Steering Committee members for a regional public forum regarding revision of the National Aquaculture Development Plan and three National Aquaculture Extension Workshops/Conferences.
- Served as writers and reviewers of several white papers for NCRAC.
- Served as Steering Committee members of state-specific aquaculture conferences as well as state aquaculture coordinating councils.

OBJECTIVE 2

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR (currently less than 3.0 full time equivalents). A NCRAC white paper on extension presents several strategies to address this concern.

Networking of specialists and Cooperative Extension Service (CES)-designated contacts has maximized efficiency of education programs and minimized duplication. Individual state extension contacts often respond to 120+ annual calls from outside their respective state as well as interacting with colleagues with mutual concerns related to developing aquaculture activities. Many of these requests have been met by providing fact sheets, technical bulletins, bibliographies, maintenance of list servers, and detailed responses to both generalized and specialized questions. This extension network is critical to being able to match specific aquaculture questions with the best source of information, e.g., crawfish and leech information with Gunderson; yellow perch information with Garling, Binkowski, and Tiu; and sunfish information with Morris.

The Aquaculture Network Information Center (AquaNIC [http://aquanic.org/]) was established at Purdue University in 1994 through funds from USDA's Cooperative State Research, Education, and Extension Service and the Illinois-Indiana Sea Grant Program. AquaNIC hardware is housed in the Department of Animal Sciences at Purdue University and is coordinated by the Mississippi-Alabama Sea Grant Consortium, the Alabama Cooperative Extension System, and the Illinois-Indiana Sea Grant College Program.

AquaNIC was the first U.S. aquaculture Web site and is globally one of the most widely accessed and cited aquaculture Web sites. More than 1,000 individual, educational, commercial, and governmental Web sites link to AquaNIC as a source of online aquaculture information. In the past year, the number of "hits" to the NCRAC Web site, newsletters, and publications was 79,005, 9,557, and 27,702, respectively.

Aquaculture handbooks have been developed and distributed to each NCRAC-designated aquaculture extension contact and selected CES and Sea Grant field staff member.

As with any organization, there have been changes in NCRAC extension personnel since the inception of the project. For instance, Landkamer was the primary aquaculture extension contact for Minnesota. In the intervening years, he was replaced by Kapuscinski and then by Gunderson. Two other individuals were replaced in 1994. In Kansas, Neils replaced Henderson and in Illinois, Kohler replaced Selock. Lee replaced Neils in Kansas in 1996. Hochheimer, who replaced Ebeling in Ohio, left Ohio State University; Tiu was appointed as the aquaculture extension specialist for Ohio in 1998. Sanders was appointed as the extension contact for North Dakota in 1998 replacing Klinkebiel. Upon Sanders resignation, Brian Stange followed and was replaced by Paul Jarvis in 1999. Chet Hill replaced Jarvis in 2002. Jerry Mills is now the appointed NCRAC Extension contact for South Dakota. As of 1999, Kayes is no longer with Nebraska Extension; to date no replacement has been designated. In 2000, Swann resigned from Purdue/Illinois Sea Grant; that position is currently open with Michael Plummer serving Illinois and Brian Miller serving Indiana in the interim.

OBJECTIVE 3

In-service training for CES and Sea Grant personnel and other landowner assistance personnel have been held in most of the states in the region. Training has been in the areas of basic aquaculture, species-specific technologies, e.g., yellow perch, and safe seafood handling including Hazard Analysis

Critical Control Point (HACCP). Many of these individuals have, in turn, trained industry representatives in respective subject matter.

To help prevent the spread of aquatic nuisance species (ANS) via cultured fish and baitfish, and to provide the industry with a tool to demonstrate to natural resource agencies that private fish culturists can provide a ANS-free product, the ANS-HACCP approach was developed by Gunderson and Kinnunen. Developed materials include a manual and video for use in the training sessions as well as a related poster for use in for retail outlets.

The National Association of County Agricultural Agents Annual Meeting and Professional Improvement Conference was held July 13-18, 2003 in Green Bay, Wisconsin. NCRAC extension contacts who participated in this workshop included Morris, Gunderson, and Kinnunen.

OBJECTIVE 4

A number of workshops, conferences, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented. There have been regional workshops on general aquaculture, fish diseases, HACCP training, fish nutrition, commercial recirculation systems, leach and baitfish culture, aquaculture business planning, crayfish culture, pond management, culture of specific taxa (yellow perch, hybrid striped bass, rainbow trout, hybrid walleye, and sunfish), and in-service training for high school vocational-agricultural teachers. Depending on the workshop, the number in attendance often exceeded 100.

Four North Central Regional Aquaculture Conferences have been held. The first in Kalamazoo, Michigan was held in March 1991; the second was held in February 1995 in Minneapolis, Minnesota; the third conference was held in Indianapolis, Indiana; and the fourth was held February 1999 in Columbia, Missouri. These regional meetings were attended by hundreds of individuals including persons from Canada.

On April 10, 1993, over 700 viewers from 35 states and Canada watched the first national interactive teleconference on aquaculture, "Investing in Freshwater Aquaculture," that was broadcast from Purdue University. It was a televised satellite broadcast for potential fish farmers. The program consisted of 10 five- to seven-minute video tape segments that addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish.

A Yellow Perch Producers' Forum was conducted in Hudson, Wisconsin on January 21-22, 2000. NCRAC extension contacts helped design the forum, the goals of which were to: (1) increase profitability and sustainability of existing perch producers, (2) increase cooperation between and among producers, researchers, and extension personnel, and (3) identify yellow perch research and extension needs. A summary of research and extension needs identified by the producers was compiled.

Kinnunen was instrumental in developing and compiling support for the "Environmental Strategies for Aquaculture Symposium." This two-day meeting took place during the 62nd Midwest Fish and Wildlife Conference in Minneapolis, Minnesota, December 3-6, 2000. The symposium provided a forum where industry, resource management agencies, and environmental/conservation organizations could discuss the scientific information available and/or needed to make reasoned decisions regarding aquaculture development. Several NCRAC state aquaculture extension contacts, i.e., Gunderson, Morris, Kinnunen, and Tiu, participated in the planning of or made presentations at this symposium.

In 2000, a workshop, entitled "Organic Aquaculture Standards Workshop," was developed and supported by Minnesota extension contacts. With support from the USDA's Agricultural Marketing Service, Packard Foundation, and the University of Minnesota's Extension Service, 43 national and international participants came together to address issues of concern regarding the National Organic Standards Board's organic aquaculture standards.

NCRAC extension contacts have served as editors for regional aquaculture newsletters as well as in-state aquaculture associations; served on state aquaculture advisory councils and state aquaculture task forces; and assisted in the planning and implementation of state aquaculture association meetings. Often the individual contact is the principal contact between the aquaculture industry and governmental/academic institutions.

In support of extension activities being funded through research projects, i.e., hybrid striped bass and sunfish research projects, extension specialists have completed fact sheets, book chapters, and videos. These extension materials, arising from the combined efforts of both extension specialists and researchers, will help to address many questions concerning aquaculture in the NCR.

In addition to the previously mentioned areas, NCRAC extension contacts have been instrumental in fostering the continued growth of the aquaculture industry in the region. For example, Pierce created the Cooperative Extension Aquaculture and Marketing Educational Program to facilitate the development and implementation of aquaculture educational programs in Missouri. Tiu has also worked to revitalize the Ohio Aquaculture Association (OAA). She has continued to coordinate monthly OAA board meetings and edit the OAA newsletter. Gunderson has worked to distribute information about the Environmental Assessment Tool for Land-based Aquaculture developed by Kapuscinski (University of Minnesota) under contract by the Great Lakes Fisheries Commission. This instrument has the ability to impact aquaculture in much of the NCR. Lee has worked with the Kansas Aquaculture Association to develop and fund a current directory of Kansas fish producers.

Many of the NCRAC extension contacts have worked with industry and governmental representatives to produce state aquaculture plans and improved governmental regulations. Binkowski has worked with the Wisconsin Department of Agriculture, Trade and Consumer Protection in the production of A Wisconsin Aquaculture Industry Profile Processor Survey 1998 and 1998 Wisconsin Aquaculture Directory. Binkowski has also worked with the State of Wisconsin as well as the Wisconsin Aquaculture Association to plan the establishment of the Northern Wisconsin Aquaculture Demonstration Facility in Ashland, Wisconsin.

All fish processors, including those who handle aquaculture products, are now required by law to process their fish following HACCP guidelines. Kinnunen has conducted numerous HACCP training workshops throughout the NCR. These workshops served to train fish processors on the principles of HACCP and to give them knowledge on how to develop and implement a HACCP plan for their specific facility. Kinnunen coordinated a three-day HACCP course at St. Croix Waters Fishery near Danbury, Wisconsin, one of the largest recirculation aquaculture systems in North America, in 2002.

NCRAC extension contacts have been responsive to arising issues for the NCR aquaculture industry. For instance, the aquaculture industry is accused of being an important vector for the spread of exotic species like zebra mussels, Eurasian watermilfoil, round goby, and others because water and organisms are moved from one water body to another. Michigan and Minnesota extension contacts worked with other aquaculture and exotic species specialists from around the region to address this issue important to many fish farmers in the NCR, especially people raising fish for stocking or baitfish. To better identify the risks of spreading exotic species and to reduce those risks, a HACCP approach was used. Extension specialists in Illinois/Indiana, Michigan, Minnesota, and Ohio are participating in this project. The project is designed to identify critical control points and to develop guidelines for controlling the spread of exotic species while not overburdening the industry with unnecessary regulations.

In-service training of secondary teachers have taken placed in a number of states. For instance, teachers in Iowa, Ohio, and Wisconsin have received instruction in aquaculture which they can use in their vocational agriculture courses.

Several states have on-site facilities that are used for extension programming. For instance, the facilities in Piketon, Ohio operated by Ohio State University are used to inform the public about aquaculture as well as foster grass root support for this agriculture enterprise. The aforementioned Northern Wisconsin Aquaculture Demonstration Facility has also been used in a similar fashion.

The National Catfish Information Database has proceeded with Swann serving on the planning committee as well as serving as a lead editor. The Aquaculture Business Plan Guide has been completed by Southern Illinois University-Carbondale staff.

The NCR is dotted with unused agriculture buildings harkening to the days when small farms could survive raising small numbers of hogs or chickens. One option that many are exploring is converting the buildings for aquaculture use. To help farmers further explore this option, a videoconference workshop was designed and produced to explore the pros and cons of converting existing agricultural buildings into fish culture facilities. This workshop, held November 16, 2002, in Lima, Ohio was sponsored by NCRAC, Ohio State University, and the OAA, and was broadcast to several sites throughout the Midwest, including Illinois, Iowa, and Missouri. Notebook materials from this workshop are available online at http://southcenters.osu.edu/oaa/.

OBJECTIVE 5

Working interactively, Binkowski and Steve Yeo, at the University of Milwaukee Great Lakes WATER Institute, and Morris, the Associate Director of NCRAC, at Iowa State

University, have prepared a draft publication entitled “Aquaculture Effluents and Waste By-Products: Potential Recovery and Beneficial Use in the North Central Region.” Final printing of this document is expected to be spring 2004.

The Yellow Perch Culture Guide is currently in review; Garling is supervising the final production of this document. Final publication is expected to be in 2004.

Kohler and Ryan Lane are currently finishing a CD for NCRAC concerning hybrid striped bass culture. The information on this CD is multifaceted in regard to the various culture phases of hybrid striped bass, i.e., egg through food-fish or pure parental brood stock.

In addition, numerous fact sheets, technical bulletins, and videos have been written or produced by various participants of the Extension Work Group. These are listed in the Appendix.

WORK PLANNED

Efforts will continue in regard to strengthening linkages between research and extension work groups as well as enhancing the network for aquaculture information transfer. Participants will also continue to provide in-service training for CES, Sea Grant, and other land owner assistance personnel.

Educational programs and materials will be developed and implemented. This includes final publication of the Yellow Perch Culture Guide.

Future HACCP workshops will be planned as needed in the NCR. Any additional workshops developed and hosted by state extension contacts will be advertised in surrounding states to take advantage of the NCRAC extension network and the individual expertise of Extension Work Group participants.

IMPACTS

- In-service training for CES and Sea Grant personnel has enabled those professionals to respond to initial, routine aquaculture questions from the general public.
- Development of aquaculture education programs for the NCR has provided “hands-on” opportunities for prospective and experienced producers. More than 6,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group.
- Fact sheets, technical bulletins, and videos have served to inform a variety of clients about numerous aquaculture practices for the NCR. For instance, “Making Plans for Commercial Aquaculture in the North Central Region” is often used to provide clients with initial information about aquaculture, while species-specific publications on walleye, trout, and catfish have been used in numerous regional meetings and have been requested by clients from throughout the United States. Publications on organizational structure for aquaculture businesses, transportation of fish in bags, and others are beneficial to both new and established aquaculturists. It has been estimated that NCRAC publications were used to address approximately 15,000 client questions annually.
- NCRAC extension outreach activities have helped to foster a better understanding and awareness for the future development of aquaculture in the region.
- AquaNIC has become an entry point for many people searching for aquaculture information on the Web. AquaNIC’s

home page now averages more than 3,000 visits per month by people from more than 50 countries.

- Fish processors who have attended NCRAC-sponsored HACCP Training Workshops have learned the principles of HACCP with regards to its importance in insuring the production of a safe fishery product. HACCP Plans have now been implemented by workshop attendees who are now keeping records of their daily processing and Sanitation Standard Operating Procedures. About 200 fish processors and/or aquaculturists attended HACCP Training Workshops.
- Kinnunen and Gunderson have been leaders in the development of ANS-HACCP workshops and materials. Attendees to these workshops have included commercial culturists as well as cuturists with natural resource agencies. Many of these individuals have implemented many of the principles of ANS-HACCP into their operations.
- In Ohio, an organized OAA has allowed producers to have the forum necessary to encourage appropriate legislation necessary for the success of the aquaculture industry. Closer working relationships with the Ohio Department of Natural Resources resulted in the first electronic database of Aquaculture Permit Holders in Ohio. Two individuals who attended the Alternative Aquaculture Production workshop in Ohio have converted their barns and are now raising fish.

PUBLICATIONS, MANUSCRIPTS, WORKSHOPS, AND CONFERENCES

See the Appendix for a cumulative output for all NCRAC-funded Extension activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-91	$107,610	$237,107				$237,107	$344,717
1991-93	$94,109	$152,952				$152,952	$247,061
1993-95	$110,129	$198,099		$250,000	$55,000	$503,099	$613,228
1995-97	$31,204	$149,325	$5,000	$84,000		$238,325	$269,529
1997-99	$38,000	$110,559				$110,559	$148,559
1999-01	$94,000	$108,124				$108,124	$202,124
2001-03	$46,500	$99,702				$99,702	$146,202
TOTAL	$521,552	$1,055,868	$5,000	$334,000	$55,000	$1,449,868	$1,971,420

ECONOMICS/MARKETING[2]

Project Termination Report for the Period
September 1, 1999 to August 31, 2003

NCRAC FUNDING LEVEL: $47,916 (September 1, 1999 to August 31, 2003)

PARTICIPANTS:

Ronald E. Kinnunen	Michigan State University	Michigan
Edward M. Mahoney	Michigan State University	Michigan
William C. Nelson	North Dakota State University	North Dakota
Patrick D. O'Rourke	Illinois State University	Illinois
Industry Advisory Council Liaisons:		
Curtis Harrison	Harrison Fish Farm, Hurdsville	Missouri
David A. Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan

REASON FOR TERMINATION

The project objectives were completed.

PROJECT OBJECTIVE

Evaluate the potential "supply" and "market" for hybrid walleye (female walleye × male sauger) and sunfish (female green sunfish × male bluegill) fillets relative to comparable fish.

Sub-objectives:

(1) To analyze information on the consumption and "supply" of comparable fish in the U.S. and the North Central Region (NCR).

(2) To provide a technical comparison of the qualities and attributes of hybrid walleye (female walleye × male sauger) and sunfish (female green sunfish × male bluegill) fillets with those of substitute fish.

(3) Assess consumer (supermarket/consumers and restaurant/consumers) perceptions and likelihood of purchasing hybrid sunfish and walleye fillets relative to substitute fish.

(4) Evaluate the likelihood (and conditions, e.g., supply available, fillet sizes, price) that wholesaler, institutional buyers, and major fish retailers will add hybrid walleye and sunfish to their product lines.

(5) Assess the potential interest and perceived barriers to the commercial production of hybrid sunfish and walleye.

[2]NCRAC has funded four Extension/Marketing projects. Termination reports for the first two projects are contained in the 1989-1996 Compendium Report; a termination report for the third project is contained in the 1996-97 Annual Progress Report. The first project was chaired by Donald W. Floyd; the second was chaired by Leroy J. Hushak; and the third was chaired by Patrick D. O'Rourke. This termination report is for the fourth Economics/Marketing project which is chaired by Edward M. Mahoney. It was originally a 2-year project that began September 1, 1999 but was lengthened for an extra year for no additional cost.

(6) Estimate the "supply" and "demand" for hybrid walleye and sunfish fillets.

PRINCIPAL ACCOMPLISHMENTS

SUB-OBJECTIVE 1

Data and information on the U.S. fish industry was gathered by North Dakota State University (NDSU). This was accomplished by searching public and private sources of information and statistics, i.e., government statistics, professional aquaculture association Web pages, commercial aquaculture Web pages, and a literature review of journals, other media, and conference proceedings.

U.S. consumption of fish and seafood products has been relatively steady over the last decade at about 15 lb/capita. The fish industry lacks a strong national promotion group due partially to its fragmentation into specific species organizations. In order to increase per capita consumption, the industry needs to work together. Expenditures for fish products in the NCR are substantially lower than in other regions of the United States and the major types of fish consumed are not produced or caught in the region. Again, these facts lead to the need for a strong regional organization.

SUB-OBJECTIVE 2

A preliminary consumer blind taste-testing of wild-caught walleye and sunfish was conducted at the annual meeting of the Minnesota Aquaculture Association in February 2000. Based upon preliminary surveys of behavior and taste-testing, walleye exhibits great potential demand. Walleye is a preferred species in the region and possesses characteristics demanded by fish consumers. Sunfish, although a sought after fish by anglers, was not received favorably by consumers in the taste-testing experiments. Farm raised hybrid walleye was also rated high in taste tests at the Hybrid Walleye Workshops in Cadillac, Michigan (February 2002) and Cape Girardeau, Missouri (March 2003).

SUB-OBJECTIVE 3

A preliminary general consumer survey was conducted at five sites: the Minnesota Aquaculture Association in February 2000 (51 surveys completed); the Wisconsin Aquaculture Association in March 2000 (46 surveys completed); the Indoor Aquaculture Field Day, Vandalia, Illinois in March 2000 (22 surveys completed); a Hazard Analysis Critical Control Point training program conducted by Kinnunen in East Lansing, Michigan in August 2000 (20 surveys completed); and the Hybrid Walleye Workshop, Cape Girardeau, Missouri in March 2003 (16 surveys completed). A total of 155 surveys were completed in 2000 and 2003. There was substantial difference in consumer behavior within the region with Indiana and Michigan being similar and Minnesota and Wisconsin consumers having similar patterns of consumption behavior. Missouri is definitely catfish country as there was a high preference for that species in that region of the country.

Walleye was the clearly preferred fish in consumer perceptions, scoring the highest in comparison to orange roughy, cod, and sunfish in each category of appearance, flavor, mouthfeel, and overall. Sunfish scored last in the same comparison, similar to tilapia in an earlier study. These consumer sensory tests, along with supplier opinions and market information, provide strong rationale for continued research on production of walleye and for expansion of farm-raised walleye. Given the difficulty of competing with low cost imports, the region needs to focus on "high-end" species. Sunfish, with only one exception, was rated low as to commercial potential. The widespread familiarity with sunfish as the most commonly caught fish did not result in strong market potential and work completed in Indiana and Michigan supported the common knowledge in food markets, i.e., consistent quality, taste, and appearance are the most important attributes in marketing fish products.

SUB-OBJECTIVE 4

During Year 1 of the study Michigan State University (MSU) took the lead in regard to the wholesaler and buyer analysis. MSU completed a literature review of previous studies that collected information from seafood wholesalers and buyers. This included obtaining survey instruments used to collect information from these and similar businesses. The literature review provided a conceptual basis for development of a draft survey instrument to be used to collect information from “seafood” brokers and distributors, institutional buyers, and major fish retailers in the seafood business.

The draft survey collected information on: (1) gross fish purchases, (2) cost of all fish bought/brokered, (3) species of fish bought or sold, (4) percentage of fish they buy or sell that are wild-harvested saltwater fish, wild-harvested freshwater fish, and farm-raised fish, (5) percentage of fish that they buy or sell that are fresh whole, fresh fillet/steaked, frozen whole, frozen fillet/steaked, and live, (6) the importance of different attributes in deciding whether or not to buy or carry a particular finfish product, (7) whether they purchase/sell or have purchased/sold wild-harvested walleye, farm-raised walleye, wild-harvested sunfish, or farm-raised sunfish, (8) for which fish species would farm-raised walleye and sunfish be a substitute, and (9) what, if any, are the potential barriers to introducing farm-raised walleye and sunfish into their markets. The survey instrument collected information about the seafood brokers and distributors, institutional buyers, and major fish retailers and will have uses beyond the objectives of this study including regular monitoring of these businesses as it relates to purchase and sale of aquaculturally-raised fish.

MSU also evaluated different approaches for collecting information from businesses including food processors. The review of different methods (e.g., mail survey, fax surveys, telephone surveys, and personal interviews) resulted in a decision to utilize a mail/fax-telephone approach. Brokers and distributors, institutional buyers, and major fish retailers were mailed and faxed a questionnaire and given the option of completing it and returning it by fax or mail or though a telephone interview. A telephone interview was used to assess and correct for possible biases introduced by non-response. Non-response bias could be a major concern in studies such as these.

The draft survey was circulated by MSU to cooperators from Illinois State University (ISU) and NDSU for comment and recommended changes.

MSU developed a list of seafood brokers and distributors, institutional buyers, and major fish retailers. The list was developed by combining a list previously developed by NDSU, businesses listed in the yellow pages, and in a National Fisheries Institute publication. MSU collected telephone and fax numbers, and the names of key contact persons for 88 seafood brokers and distributors, seven major grocery retail chains, and 20 institutional buyers who had been identified. These lists were utilized as a sampling frame for the survey of brokers and distributors, institutional buyers, and major fish retailers in the seafood business questionnaires and also to later conduct product testing.

A fax and telephone survey was administered by MSU to fish wholesalers, fish retailers, and institutional buyers. The survey collected data about the types of fish (species, wild, aquacultured) sold and/or purchased, source (suppliers) of fish, attributes important in deciding what fish to handle, and their potential interest in purchasing and/or selling hybrid walleye. A total of 31 of 46 firms that brokered or bought fish in Michigan returned questionnaires. This represents a response rate of 67%. Non-respondents were contacted and were either closed, no longer in business, or declined involvement in the study. Seventeen large wholesalers of fish were identified. For the purpose of this study, firms were either categorized as large wholesalers (15 firms), small wholesalers (21 firms), retailers (5 firms), or institutions (5 organizations). In terms of who responded, 15 completed surveys were received from larger wholesalers (66%), 14 surveys from small wholesalers (66%), 4 surveys from retailers (80%), and 3 from institutions (60%).

The overall response rate for large and small wholesalers, retailers, and institutional buyers was 68%. Results indicate a very strong interest in fish that have the same attributes as hybrid walleye. Wholesalers and retailers exhibit no concern regarding their ability to market a new fish. Wholesalers and retailers indicate that there is strong consumer demand for fish with similar size and attributes as hybrid walleye. They indicate that they increasingly encounter problems acquiring enough similar fish to meet this demand. A number of the wholesalers indicated that they were eager to sample hybrid walleye. The only potential concern would be the price that wholesalers would be willing to pay aquaculture operators for the hybrid walleye.

In regards to the types of fish that these firms have bought or sold, 86% of the sample had bought or sold wild harvested saltwater fish. Sales of these types of fish represent 36.7% of total sales for those firms. Furthermore, 96.4% had bought or sold wild harvested freshwater fish. Sales of these types of fish represent 48.0% of total sales for those firms. Finally, 89.2% had bought or sold farm-raised fish. This represented 24.8% of total sales.

In regards to the types of farm-raised fish bought or sold in 2000, salmon, catfish, trout, and tilapia were the predominant species purchased or sold. Each of these types of fish were carried by more than half of the organizations surveyed

In regards to walleye, 28 respondents had bought or sold wild harvested walleye. The average length of time that they have bought or sold wild harvested walleye was 24.61 years. Furthermore, they rated their experience with wild-harvested walleye very highly (a mean of 8.96 on a ten-point scale with 10 being excellent). In regards to farm raised walleye, only 3 respondents had ever bought or sold this type of fish. The average length of time was 6.33 years and they rated their experience very high (mean of 9.67).

In regards to sunfish, 15 respondents had bought or sold wild harvested sunfish. The average length of time that they have bought or sold wild harvested sunfish was 17.57 years. Furthermore, they rated their experience with wild-harvested sunfish highly (a mean of 7.93). In regards to farm raised sunfish, only 1 respondent had ever bought or sold this type of fish. They only started carrying the fish during the past year but rated their satisfaction with the fish as excellent (a score of 10).

Forty-eight firms that bought or brokered fish in Illinois returned questionnaires that were distributed by ISU. A large number of questionnaires were returned unopened due to changes of address or an undeliverable address, indicating that several firms had ceased operations or moved out of the state. There was no attempt to determine if these firms had been replaced by newly established businesses. Among the 48 respondents, 9 firms reported that they brokered fish, 25 firms reported that they carried out wholesaler/distributor operations, and 26 firms or individuals reported that they bought fish for retail establishments. The gross fish purchases of the firms in the year 2000 were \$9,324,406 ± \$6,241,016 (mean ± S.E; *N* = 32). For those firms that brokered fish or carried out wholesaler/distributor operations, 35.3 ± 8.1% of their business was conducted with wholesalers/distributors; 8.0 ± 4.7% was conducted with institutional buyers; 32.3 ± 7.3% was conducted with restaurants; 12.7 ± 4.4% was conducted with retailers other than restaurants; 11.2 ± 5.7% was conducted with consumers; and 0.3 ± 0.3% was conducted with other unspecified types of businesses. Of those firms that reported buying for retailers or institutions, 14 were buyers for restaurants, 16 were buyers for retailers other than restaurants, and four were institutional buyers.

ISU researchers found that with regard to the types of fish handled or brokered, the firms reported that 42.3 ± 4.8% of their transactions were related to wild-harvested saltwater fish, 26.7 ± 4.4% of their transactions were related to wild-harvested freshwater fish, and 32.4 ± 4.4% of their transactions were related to farm-raised fish. The following figures reflect the number of firms that handled or brokered various species of farm-raised fish: catfish, 36; salmon, 30; tilapia, 30; trout, 25; striped bass, 14; walleye, 8; yellow perch, 5; sunfishes, 3; and other unspecified species, 2. The firms reported the following distribution of farm-raised fish sales: salmon, 34.1 ± 5.4%; catfish, 31.7 ± 5.7%; tilapia, 20.8 ± 5.1%; trout, 7.2 ± 1.7%; striped bass, 2.1 ± 0.7%; yellow perch, 1.7 ± 0.9%; walleye, 1.6 ± 0.9%; sunfishes, 0.5 ± 0.3%; and other unspecified species, 0.3 ± 0.3%.

The ISU questionnaire revealed 29 firms reporting transactions involving wild harvested walleye over the past 22.4 ± 3.8 years. They rated their overall experience with wild-harvested walleye at 8.0 ± 0.4 (0 = unacceptable, 10 = positive). Nine firms reported transactions involving wild-harvested sunfishes over the past 30.7 ± 8.8 years. They rated their overall experience with wild-harvested sunfishes at 6.9 ± 0.5 (0 = unacceptable, 10 = positive). Transactions involving farm-raised walleye were reported by four firms, and transactions involving farm-raised sunfishes were reported by one firm. Twelve firms rated the food quality of farm-raised walleye, based upon experience, perception, or both at 7.8 ± 0.5 (0 = unacceptable, 10 = positive). Six firms rated the food quality of farm-raised sunfishes, based upon experience, perception, or both, at 8.2 ± 0.5 (0 = unacceptable, 10 = positive). Respondents were asked to rate 15 attributes that could potentially influence whether they would buy or sell a particular finfish product. The highest rating was assigned to “consistent quality of supplied fish” (9.6 ± 0.1), and the lowest rating was assigned to “low price” (6.7 ± 0.4). Respondents were also asked to provide information about the various forms of fish that they purchased or brokered.

SUB-OBJECTIVE 5

This objective was jointly completed by ISU and MSU. Clearly, lack of marketing support and lack of product quality are the two most important potential barriers for the successful introduction of farm-raised walleye and sunfish. Furthermore, these farm-raised fish will have to directly compete with wild walleye and sunfish.

The information collected indicates there are potential markets for farm-raised walleye and sunfishes, although the support for walleye appears to be stronger than the support for sunfishes. Walleye, and to a limited degree, sunfishes are possible substitutes for a number of saltwater and freshwater species. Keys to successful market development appear to be consistent high quality with emphasis on taste and appearance, guaranteed year-round supplies, competitive pricing, and strategically placed product promotion. Product forms most commonly used by fish buyers include fresh whole, fresh fillet, and frozen fillet.

Based upon surveys of behavior and taste-testing as well as market analysis, walleye and hybrid walleye exhibits the greatest current and potential demand. It is a preferred species in the region and possesses characteristics demanded by fish consumers as verified by its market price and responses by the industry. It appears that reduction of production problems and costs are the only limiting factor to a substantial increase in walleye production and sales.

Sunfish, although a sought after fish by anglers, was not received favorably by consumers in the taste-testing experiments. It also was not one of the favored species in the survey of consumption behavior. Based upon current information, sunfish will sell at a much lower price than walleye and will need to be produced at much lower cost per pound to be profitable. Although sunfish has name recognition, it appears that it would compete at a level with tilapia fillets based on its similarity in consumer response to taste and appearance tests.

SUB-OBJECTIVE 6

Results indicate that walleye and hybrid walleye are preferred fish in the region. Both consumer reaction and the industry responses clearly indicate expansion possibilities for increased walleye production without a high probability of negative price effects.

IMPACTS

Based upon the surveys of behavior and taste-testing, walleye exhibits great potential demand. It is a preferred species in the region and possesses characteristics demanded by fish consumers. It appears that production problems and costs are the only limiting factors to a substantial increase in walleye production and sales.

Sunfish, although a sought after fish by anglers, was not received favorably by consumers in the taste-testing experiments. It also was not one of the favored species in the survey of consumption behavior. Additional analysis of the hybrid sunfish needs to be undertaken prior to any firm conclusions or recommendations, however, based upon current information, sunfish will sell at a much lower price than walleye and will need to be produced at much lower cost per pound to be profitable.

The preliminary survey of wholesalers, retailers, and institutional buyers reveals that there is significant interest in hybrid walleye. Wholesalers and retailers are unable to acquire sufficient “similar” fish to meet current consumer demand. Wholesalers and retailers do not believe that “newness” would be a barrier to marketing the fish because walleye has significant positive name recognition. The process of conducting the survey created awareness and interest concerning hybrid walleye. A number of the wholesalers and retailers were interested in receiving more information including suppliers. Others expressed interest in taste and market testing of hybrid walleye. This implies that marketing the fish would not be difficult or costly.

RECOMMENDED FOLLOW-UP ACTIVITIES

The completed project strongly indicated that a market exists for walleye in the NCR, now refinement of production techniques subject to cost limits appear to be the next step toward a successful walleye aquaulture industry in the NCR. The follow-up activities that could help in a future walleye aquaculture industry in the region include in sequential order:

- Identify very clearly why a market hasn't developed so far,
- Address those issues through research, and, if successful, conduct a complete revenue/cost analysis from the producer's perspective. If profitable, provide extension materials and "hands-on" management assistance to producers.
- Conduct a marketing test of those fish in upscale or white tablecloth restaurants, and
- Analyze the potential for a regional promotion program which would include farm-raised walleye.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Economics/Marketing activities.

SUPPORT

YEAR	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-00	$27,822	$53,777				$53,777	$81,599
2000-01	$20,094	$55,910				$55,910	$76,004
TOTAL	$47,916	$53,777				$109,687	$157,603

YELLOW PERCH[3]

Progress Report for the Period
September 1, 2001 to August 31, 2003

NCRAC FUNDING LEVEL: $326,730 (September 1, 2001 to August 31, 2003)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Indiana
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Donald J. McFeeters	Ohio State University	Ohio
David A. Smith	Freshwater Farms of Ohio, Inc.	Ohio
Laura G Tiu	Ohio State University	Ohio
Geoffrey K. Wallat	Ohio State University	Ohio
Industry Advisory Council Liaison:		
Rex Ostrum	Ostrum Acres Fish Farm, McCook	Nebraska
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-Funded Collaborators:[4]		
Pat Brown	Red Lake Hatchery, Redby	Minnesota
Harvey Hoven	University of Wisconsin-Superior	Wisconsin
David L. Northey	Coolwater Farms, LLC, Deerfield	Wisconsin
Todd Powless	Zeigler Brothers, Inc., Gardners	Pennsylvania
Lloyd Wright	Hocking Technical College, Nelsonville	Ohio
Tom Zeigler	Zeigler Brothers, Inc., Gardners	Pennsylvania

PROJECT OBJECTIVES

(1) Develop or investigate reliable, profitable, and sustainable production systems to rear feed-trained yellow perch to market size.

(2) Continued development of grow-out diets and feeding strategies for feed-trained yellow perch in ponds and recirculating systems.

[3]NCRAC has funded eight Yellow Perch projects. Termination reports for the first three projects are contained in the 1989-1996 Compendium Report; a termination report for the fourth and fifth projects is contained in the 1997-98 Annual Progress Report; a project component termination report for two objectives of the sixth project is contained in the 1999-00 Annual Progress Report; and a project component termination report for the remainder of the sixth project and the seventh Yellow Perch project is contained in the 2000-01 Annual Progress Report. This progress report is for the eighth Yellow Perch project which is chaired by Jeffrey A. Malison. It is a 3-year project that began September 1, 2001.

[4]Sunny Meadow Fish Farm and Willow Creek Aquaculture, who were included in the Project Outline as non-funded commercial cooperators, have withdrawn from the study. Red Lake Hatchery chose not to participate in the first year of the project.

(3) Extension
   a. Conduct additional yellow perch forums and publish proceedings.
   b. Develop fact sheets that not only review the literature but also indicate successes and failures of commercial yellow perch aquaculture.
   c. Identify a yellow perch information specialist who can visit state associations.

ANTICIPATED BENEFITS

The work conducted under Objective 1 will document the production parameters (including expected growth and survival rates, food conversion, and density and loading limitations) that can be expected using open pond, net pen, flow through, and recirculation systems. In addition, information will be generated on the relative costs of raising market-size yellow perch using different types of systems. This information will be made available to outreach specialists, who can then make informed recommendations to current and prospective perch producers regarding the most profitable methods for producing yellow perch. The work conducted under Objective 1 will also provide opportunities for individuals interested in yellow perch aquaculture to observe different production systems and management strategies. The studies conducted under Objective 2 will provide key information on the best available diets and feeding strategies for raising yellow perch to food size. This information, in turn, should help perch producers increase their efficiency by maximizing fish growth rates, improving food conversion, and reducing food costs. The extension efforts conducted under Objective 3 will provide updates on the status of yellow perch culture in the North Central Region (NCR) and help transfer the latest technological innovations to the industry.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Research has been conducted by the University of Wisconsin-Madison (UW-Madison) to document key production parameters for raising feed-trained fingerlings to market size in ponds in southern Wisconsin, using best current practices at three densities.

In May 2002, four ponds (two ponds, each at the Lake Mills State Fish Hatchery and at Coolwater Farms, LLC, Deerfield, Wisconsin) were stocked with age-1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) at 37,200 fish/ha (15,055 fish/acre) and maintained using best management practices. Throughout the summer, the fish in each pond were fed daily to satiation (at dusk) using a standard floating trout grower diet. In general, a strong feeding response was observed in all of the ponds. The fish were sampled regularly for weight and length, and the sampling indicated that the fish in all four ponds were growing well (0.25–0.40 g/day; 0.009–0.014 oz/day). Water quality measurements taken throughout the summer indicated that ammonia and nitrite concentrations were always negligible, and dissolved oxygen (DO) levels were always at or above the level needed to allow for good perch growth (3 mg/L; ppm). Except for a 2-week period during a mid-July heat spell, water temperatures remained below 27°C (80.6°F). During the heat spell, however, temperatures increased to 27–28°C (80.6–82.4°F) , and the feeding activity of the fish diminished. The fish were harvested in late October. Fish growth was very uniform both between and within ponds. The fish gained an average of 57 g (2.0 oz) and 7.3 cm (2.9 in) during the growing season. Mean survival was 83%. Feed conversion at the Lake Mills ponds averaged 2.5, which was significantly poorer than that at ponds at Coolwater Farms. This problem results from the fact that ducks ate a significant amount of food at the Lake Mills ponds. Ducks cannot be actively chased away from these ponds because they are part of a publicly-owned hatchery in the middle of a city. Because of this problem, a greater emphasis will be placed on feed conversion data obtained from ponds at Coolwater Farms than at Lake Mills.

In May 2002, three ponds at the Lake Mills Hatchery were stocked with age-1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) in the following manner: one pond at 37,200 fish/ha (15,055 fish/acre), one pond at 49,600 fish/ha (20,073 fish acre), and one pond at 62,000 fish/ha (25,091 fish/acre). Otherwise, these ponds were treated exactly like those described above in Objective 1. Throughout the growing season no obvious density-related differences were observed in fish production characteristics or water quality. The final weight gain, length gain, and survival rates of the fish raised at low, medium, and high densities, respectively, were: 57 g, 7.2 cm (2.0 oz, 2.8 in), and 72%; 50 g, 7.2 cm (1.8 oz, 2.8 in), and 85%; and 55 g, 6.0 cm (1.9 oz, 2.4 in), and 100%.

All of the studies done in 2002 were repeated in a similar manner in 2003, to gain additional replicates. At the time of this report, the final 2003 data had not yet been collected.

Ohio State University (OSU) researchers concurrently used three types of production systems supplied by the same water source (lake water) to rear feed-trained yellow perch fingerlings to market size. The rearing systems used were 6, 2,044-L (540- gal) flow-through tanks, 6, 3,785-L (1,000- gal) flow-through raceway tanks, and 6, 3,028-L (800-gal) cages placed in ponds. Production stocking rates of 60 g/L (0.5 lb/gal) for flow-through tanks were used to calculate the density of feed-trained fingerlings placed in each system. Two feeding strategies were also employed (percentage body weight and satiation feeding), with three replications in each system. Both growth performance data (feed conversion ratios, weight gain, and survival) and economic data (e.g., labor hours, purchase price of systems, construction costs, system operating costs, feed costs) were collected for all three systems and both feeding strategies.

Due to excessive mortalities experienced during the first year of culture at OSU sites, the surviving fish were held in a pond over the winter. These fish were randomly mixed with a new group of similar age and size yellow perch in mid-April 2003, and restocked to the raceways, round tanks, and cages. At the beginning of the second year of culture, fish had a mean weight of 23 g (0.8 oz), and mean total length of 13.2 cm (5.2 in). Initial stocking densities in all three systems was approximately 10 g/L (0.08 lb/gal). The low stocking density was necessary due to the lower number of fish available than anticipated, and the need to have equal stocking densities in all three systems.

DO and temperature were recorded daily in all systems. Water quality parameters (total ammonia, nitrite, pH, alkalinity, hardness, and carbon dioxide) were monitored weekly. Fish were fed twice daily, according to feeding regime (% body weight or satiation). The initial % body weight amount was set at 3% per day. Satiation feeding treatments had total feed distributed weighed and recorded daily. Mortalities were counted and removed daily.

Fish were sampled once a month for weight and length gain, and feed rations were adjusted accordingly. Approximately 10% of the population was sampled at this time. Due to the length of time in sampling, one replicate from each treatment was chosen at random for sampling each month. All three replicates feed amounts were adjusted to the new rates based on this sampling technique.

Mean temperature and DO readings had similar ranges in all three treatments from April through July 2003 (August data was not available at time of reporting). Mean temperature readings for round tanks, raceways, and pond cages, respectively, by month were: April—15.6, 16.1, and 16.8°C (60.1, 61.0, and 72.0°F); May—19.1°C (66.4°F) in all three; June—21.0, 21.1, and 22.2°C (69.8, 70.0, and 72.0°F); and July—24.3, 24.4, and 24.5°C (75.7, 75.9, and 76.1°F). Similarly, DO readings in ppm were: April— 6.9, 7.4, and 8.3; May—6.8, 6.5, and 7.0; June—6.0, 5.9, and 6.6; and July—5.6, 5.5, and 6.0. Ranges for the following parameters are reported for tanks, raceways, and cages, respectively: total ammonia in ppm (0.0–0.8, 0.0–0.8, and 0.0–0.9); nitrite in ppm (0.01–0.05, 0.00–0.03, and 0.00–0.05); pH (7.25–7.5, 7.25–7.5, and 7.5–8.5); alkalinity in ppm (17.1–51.3 for all three); hardness in ppm (85.5–102.6 for all three); and carbon dioxide in ppm (10–20, 10–20, and 5–15).

In comparing production parameters by rearing systems through August 2003, pond cages had the largest individual weight gain (79.4 g; 2.8 oz), followed by round tanks (60.1 g; 2.1 oz), and raceways (60.1 g; 2.1 oz) as well as for individual length gain (6.1, 4.9, and 4.6 cm, respectively [2.4, 1.9, and 1.8 in]). Raceways exceeded all other treatments for estimated total bulk weight (67.3 kg; 148.4 lb), followed by pond cages (60.4 kg; 133.2 lb), and round tanks (44.0 kg; 97.0 lb). This may be due, in part, to the higher survival rates obtained in the raceways (93%), versus the pond cages (76%), and the round tanks (73%). Feed conversion ratios were lowest for the raceways (1.5), followed by the pond cages (1.8), and round tanks (2.1).

In comparing feeding strategy (% body weight to satiation), satiation feeding treatments showed slightly higher individual weight gain (64.0–63.4 g; 2.3–2.2 oz), total bulk weight (58.2–56.3 kg; 128.3–124.1 lb), and survival (82–80%), with corresponding lower feed conversion ratio (1.6–1.9). Percentage body weight treatments showed slightly higher individual length gain (5.3–5.1 cm; 2.1–2.0 in).

Researchers at the University of Wisconsin-Milwaukee (UW-Milwaukee) have been conducting case studies using their in-house recycle aquaculture system and at two commercial facilities in Wisconsin using recycle aquaculture systems to provide comparative cost and production case histories for representative NCR recycle aquaculture operations rearing fingerling perch to marketable size. Each of these recycle aquaculture system configurations differs in significant ways that will provide information on the variety of these systems being operated by perch culturists in the NCR. Since December 2001, two cycles of grow out of fingerling perch to market size have been completed using the in-house UW-Milwaukee recirculating aquaculture system. The solids sludge from this recirculating aquaculture system has also been used to support UW-Milwaukee vermicomposting investigations in connection with the current North Central Regional Aquaculture Center (NCRAC) Aquaculture Wastes and Effluents Project. In addition to operations with the in-house recirculating aquaculture system, contact has been made with operators of two alternative recirculating aquaculture systems in Wisconsin to serve as non-funded cooperators. They have consented to cooperate and, in combination with the UW-Milwaukee system, this will provide comparative cost and production case histories for representative NCR recirculating aquaculture system operations rearing fingerling perch to a marketable size. Each of these recirculating aquaculture system configurations differ in significant ways that will provide information on the variety of recirculating aquaculture systems being operated by perch culturists in the NCR.

Case study 1 uses the UW-Milwaukee 25-m^3 (6,604 gal) recirculating aquaculture system. The system components include a 15–18 m^3 (3,963–4,755 gal) oval rearing tank, a floating bead clarifier, and a fluidized bed biofilter (approximately 5 m^3 [1,321 gal]) powered by two 1.0 hp circulating pumps. From February 2002 through October 2002, the UW-Milwaukee recirculating aquaculture system was used to conduct an initial fingerling to market-sized perch grow-out trial using approximately 10,000 yellow perch fingerlings (128 kg [282 lb] total weight). During this trial, daily records of food, water, salt, and bicarbonate usage were kept; the amount of settleable solids backwashed from the bead filter clarifier was determined; rearing water quality records were kept for pH, total ammonia nitrogen, nitrite nitrogen, DO, chloride concentration, and conductivity of the rearing water. From daily maintenance records, hours of labor required for daily system operation and incidental maintenance was estimated. Zeigler Brothers, Inc. provided perch food for the duration of this project. Monthly evaluations of perch growth performance and food conversion were made. Estimates of electrical usage for pumping, lighting, and aeration have been calculated. From UW-Milwaukee purchasing records the fixed costs of purchasing and installing this system have been documented. On October 7-8, 2002, after 231 days of operation, 9,333 perch (618 kg [1,362 lb] total weight) were harvested from this system. Overall survival during the 2002 grow-out cycle was 91%. A total of 1,015 kg (2,238 lb) of commercial perch feed was used with a production of 491 kg (1,082 lb) of perch biomass for an overall food conversion of 2.1 weight of food:weight of fish. Daily food usage was 2.5–7.0 kg/day (5.5–15.4 lb/day). Fish density in the system ranged from 7–36 kg/m^3 (0.06–0.30 lb/gal). At harvest, 55% of the fish, totaling 441 kg (969 lb), were 17.8 cm (7.0 in) or larger and usable for sale as food fish. Forty-five percent of the fish, totaling 179 kg (394 lb), were smaller than 17.8 cm (7.9 in) and would have value as stockers

In the fall of 2002, an ozonizer was installed in the UW-Milwaukee recirculating aquaculture system to aid in the reduction of the build up of small particulate and dissolved organic matter in the system, to increase water clarity, and to assist in maintaining adequate concentrations of DO. From December 18, 2002 through January 7, 2003, the UW-Milwaukee recirculating aquaculture system was restocked with 10,603 of the 2002 year class perch fingerlings (150 kg [331 lb] total weight) produced from in-house brood stock and a second grow-out cycle was begun. Data on water quality, operating costs, and monthly sampling of fish growth and food conversion were again conducted as in the previous year’s operation. These fish were reared in the system until September 25 through October 10, 2003, when 9,541 perch (650 kg; 1,433 lb) were removed from the recirculating aquaculture system. Overall survival was 90%. Daily food usage was 1.0 –9.5 kg/day (2.2–20.9 lb/day). A total of 1,767 kg (3,896 lb) of feed was used to produce 500 kg (1,102 lb) of fish for an overall conversion of 3.5 weight of feed: weight of fish. Fish density in the system ranged from 8.2–38.8 kg/m^3 (0.07–0.32 lb/gal). Fifty-one percent of the fish totaling 445 kg (981 lb) were 17.8 cm (7.0 in) or larger and usable as food-sized fish.

Forty-nine percent, totaling 205 kg (452 lb), were smaller than 17.8 cm (7.0 in) and would have value as stockers.

Case study 2 uses a privately owned and operated recycle aquaculture system. The system components include a 29-m^3 (7,661-gal) rectangular poly-lined rearing tank (with unistrut supported plywood side walls), a rotating-drum filter clarifier with a suction cleaner, and three trickling filter style biofiltration towers each with a recirculating pump operated by a 1½ hp 3-phase motor. This system has been used to rear yellow perch fingerlings to marketable size since 1995. In 2002 the system ceased to be used on a regular basis for perch grow out. The owners have provided copies of their handwritten daily logs of operation of their recirculating aquaculture system from February 1995 through August 2001. These records contain daily temperature and water quality information and numbers and dates of fish stocked into and removed either for processing and sale or as mortalities from the system. This data is being entered into computer format for analysis.

Case study 3 also uses a privately owned and operated recycle aquaculture system. The system components included 6.1-m- (20-ft-)diameter circular fiberglass rearing tanks (each approximately 36 m^3 [9,510 gal]) equipped with a dual-drain system combined with a rotating drum filter clarifier; the biofiltration system consists of three 1.1-m^3 (291-gal) poly-lined tanks and a 6.4-m^3 (1,690-gal) poly-lined tank as a biofilter reserve. One of the 1.1-m^3 (291-gal) tanks with Koch rings serves as a biofilter and O_2 contact chamber, the other two 1.1-m^3 (291-gal) biofilter tanks contain Bee-Cell 2000 filter media. The 6.4-m^3 (1,1690-gal) tank has bio-strata media and an airstone grid. The system is circulated with a ¼ hp pump. This system has been operated for several years and the owners have recently completed the system by installing a second rearing tank that was previously planned for in the sizing of the biofiltration system.

In December 2001, 17,080 fingerling perch (5.0–11.5 cm [2.0–4.5 in] total length) were stocked for growth to marketable size. The owners have harvested a portion of this cohort. In September 2002, an additional 6,000 fish were added to the system. This cooperator has supplied information on fixed costs of setting up their system, fingerling costs, and partial information on their variable costs of operation.

UW-Milwaukee has received monthly reports of daily operation, water quality conditions, and monthly operating expenses from the owners of this system from Decenber 2001 through April 2003. Over that period their reported monthly operating expenses have ranged from $365–$566 and they have harvested during this period 9,879 fish totaling 1,112 kg (2,451 lb). The owners have agreed to provide further records of this group through the period of their final removal from their system.

A preliminary trial was conducted by Freshwater Farms of Ohio, Inc. from March to August 2002. One tank in a WaterSmith System recirculating module was used to test its operational suitability for high-density perch culture. Unlike the previous demonstration research with hybrid walleye in these systems, the in-tank lighting system and the center post with the clock-sweep feeder were removed. A new fecal collection apparatus was fitted on the bottom of the 3,596-L (950-gal) conical-bottom tank. A mechanical belt feeder was installed on a board over the top of the tank, and overhead lighting controlled on a dimmer circuit was used.

To achieve the demonstration of high density, 10,000 fingerlings were put in one tank. At the time of stocking the fish were 276 to the kilogram (125 to the pound), and were approximately 7.6 cm (3.0 in) long. When they were weighed in August, the fish were 49 to the kilogram (22 to the pound) and averaged 10.8 cm (4.25 in). These perch were noticeably heavy for their length and robust. Mortalities were less than 5%. Aeration in the system was sufficient, and total ammonia was kept below 1.0 ppm. Unfortunately, technical difficulties were experienced with the heater used in this trial which did not maintain the water at the targeted temperature of 21.1°C (70.0°F). The temperature was usually around 15.5–18.3°C (60.0–65.0°F). Last fall, all fish were inadvertently lost. A second trial was to be started in spring 2003, but due to a system failure prior to initiation of the trial, the research could not begin. The system component has been redesigned and trials will be initiated next spring.

OBJECTIVE 2

Research at Purdue University (Purdue) was designed to develop the optimal dietary essential amino acid (EAA) profile to grow out yellow perch. In the initial study, six experimental diets were formulated that contained the EAA profile for fish, the predicted profile; the predicted amount plus 20%; the predicted amount plus 40%; the predicted amount plus 20% additional threonine, isoleucine, and tryptophan; or the predicted amount plus 40% additional threonine, isoleucine, and tryptophan. Highest consumption and weight gain was in fish fed the predicted essential amino acid pattern plus an additional 20% of each one. Feed efficiency was not significantly different among dietary treatments. This finding is consistent with previous studies with perch that indicated significant differences in consumption of diets, but no differences in efficiency of feed use. Results clearly indicate that if the dietary formulations are appropriate, perch will consume more food and process that food into flesh. Based on these results and results with other species, perch appear to be sensitive to changes in dietary formulations.

Studies conducted by UW-Madison are designed to compare the growth, feed conversion, and fillet yields of perch raised in ponds using three feeding strategies: fish fed to satiation once daily at dusk, fish fed to satiation twice daily at dawn and dusk, and fish fed a set ration once daily at dusk (0.5 g [0.02 oz] food/fish/day—slightly less than satiation). In May 2002, three ponds were stocked with age-1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) at 37,200 fish/ha (15,055 fish/acre). Except for the different feeding regimes, these ponds were treated exactly like those described above in Objective 1. Throughout the growing season no obvious differences were observed related to feeding regime in fish production characteristics or water quality. To date no significant differences have been observed between the three feeding regimes in any measured parameter measured. The final weight gain, length gain, and fillet yields of the fish fed a set ration or once or twice daily to satiation respectively, were: 65 g, 7.8 cm (2.3 oz, 3.9 in), and 40.6%; 55 g, 6.0 cm (1.9 oz, 2.4 in), and 40.5%; and 62 g, 8.3 cm (2.2 oz, 3.8 in), and 41.1%.

OBJECTIVE 3

UW-Milwaukee researchers gave an invited presentation at the producer's session "Overviews on Production, Nutrition, Economics and Fish Health Management for Yellow Perch" at Aquaculture America 2003, Louisville, Kentucky. They have also had outreach interactions with major regional perch producers regarding perch culture techniques, including St. Croix

Fishery, Wisconsin regarding a recirculating aquaculture system operation, a Nebraska producer on fingerling production systems, and a Minnesota producer on perch egg incubation. As part of the panel for the perch producer's session, through discussions with perch producers during the Aquaculture America 2003 conference and outreach contacts, the principal investigator has gathered valuable insight into industry opinions and needs of the perch industry. Through their recent advisory service contacts, they have gathered updated contact information on active yellow perch producers. This will identify the pool for inviting potential participants and presenters for the yellow perch workshop in early 2004. The workshop will have an industry based program with some academic presenters regarding, pond, flow through, and recirculating technology as the three major types of perch production systems. They have also given presentations connected to NCRAC Yellow Perch Work Group investigations to several producers groups and state associations (see papers presented section).

WORK PLANNED

OBJECTIVE 1

At UW-Madison, final data collection for the 2003 growing season will continue for the ponds described above. A third series of grow-out trials will be conducted in 2004. Accurate records for each pond are being kept on key economic inputs (including fingerling costs, feed costs, labor, and electricity) and outputs (including seasonal production per unit area and fillet yields). This information will be made available as <u>actual</u> production data for incorporation into the economic model previously developed by Riepe that used <u>theoretical</u> inputs and outputs.

Production experiments are slated for continuation by OSU researchers until the end of October 2003, at which time all fish will be harvested for bulk weight measurements and survivals, and counts of all market sized fish (>20 cm; 7.9 in). Final individual weight and length measurements will also be taken, and final feed conversion ratios and specific growth rates will be calculated. Economic data collected throughout the experiment (labor hours, feed costs, system operating costs, etc.) will be analyzed to develop cost of production budgets based on the three systems. Initial results are planned for presentation at the next World Aquaculture Society annual meeting, or other suitable venue.

UW-Milwaukee researchers will summarize and compare production performance and financial information obtained through consultation with owner operators and from the in-house UW-Madison recirculating aquaculture system and prepare enterprise budgets for each of the three recirculating aquaculture systems identified above. They will also attempt to recruit a third industry site to provide information from a one year production cycle. A manuscript of the case histories will be submitted for publication in a suitable journal.

Freshwater Farms of Ohio, Inc. has retro-fitted their system, has 15,000 7.6–12.7 cm (3.0–5.0 in) perch, and plans to begin growth trials in November 2003.

OBJECTIVE 2

Forty thousand yellow perch fingerlings were acquired by Purdue this year and will be grown to an advanced fingerling size. Next spring, those fish will be stocked into earthen culture ponds and fed one of three diets. Diets will be formulated using results from this year and results from previous years. Diets will contain either 32, 36, or 40% crude protein, appropriate flavor additives identified in previous studies, and high levels of soybean meal in place of fish meal. Similar diets will be fed to perch in circular tanks at the Purdue Aquaculture Laboratory and the results compared

Researchers at UW-Madison will continue their study on the effects of different feeding strategies on pond-reared yellow perch, in a manner similar to that described under Objective 1.

OBJECTIVE 3
Prior to the NCRAC annual planning meeting in early 2004, outreach personnel at UW-Milwaukee will convene a yellow perch workshop in Wisconsin. Later in 2004 a second yellow perch workshop will be held at a location in the NCR other than Wisconsin. From these workshops and through continued interaction with industry contacts, technological needs and the best business strategies for perch aquaculture will be identified. Interaction will continue with producer groups and state associations to present information on yellow perch culture and to connect them with yellow perch information specialist(s).

IMPACTS
OBJECTIVE 1
Flow-through tanks, raceways, and cages have been proven reliable and cost-effective in the rearing of several economically valuable aquaculture species (catfish, trout, and salmon). Little information is currently available for aquaculturists on the performance of yellow perch in these systems, or if these systems could be a profitable alternative to recirculating or pond rearing systems. In the experiment conducted by OSU researchers, an unusually warm summer caused higher than normal water temperatures in the deep lake reservoir. These temperatures reached sub-lethal ranges for yellow perch, and subsequently led to high mortalities in all systems. The only apparent benefit of these results may be to serve as a caution for those individuals considering culture of yellow perch in these types of systems and/or with similar water source maximum temperatures. It is apparent that these systems, especially flow-through tanks, must be maintained at temperatures below 26.0°C (78.8°F) in order to ensure high survival and increased weight gain.

The proposed field trials described under Objective 1 by UW-Madison researchers are generating baseline information on production parameters (including, but not limited to, fish growth rate, survival, and feed conversion) that can be expected for commercially raising yellow perch to food size in ponds in the upper part of the NCR. The trials will also generate detailed information that can be used to develop economic models outlining the production costs of producing food-size yellow perch using this method. In addition, information will be generated on the relative costs of raising market-size yellow perch using different types of systems. This information will be made available to outreach specialists, who can then make informed recommendations to current and prospective perch producers regarding the most profitable methods for producing yellow perch.

Analysis of results from case studies of recirculating aquaculture systems by UW-Milwaukee is ongoing, and although preliminary results have been presented in some cases completed, it is too early to identify specific impacts from the current investigations. This information is critical for individuals planning development of commercial yellow perch recirculating aquaculture system operations in the NCR.

Accumulatively, the studies conducted under this objective will generate information on the relative costs of raising market-size yellow perch using different types of systems. This information will be made available to outreach specialists, who can then make informed recommendations to current and prospective perch producers regarding the most profitable methods for producing yellow perch.

OBJECTIVE 2
Diets have been developed at Purdue and those are being tested on fingerlings (first year growth) and advanced fingerlings (second year growth). This experimental approach reassures producers of the appropriateness of diets prior to adoption on farm and the expected production characteristics. These data will be valuable as yellow perch culture and feed availability in the NCR made from regional feedstuffs continues to expand.

OBJECTIVE 3
Extension programs will provide yellow perch producers and prospective aquaculturists with information based on case studies to make informed decisions.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED
See the Appendix for a cumulative output for all NCRAC-funded Yellow Perch activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-02	$156,215	$165,327	$17,500			$182,827	$339,042
2002-03	$170,515	$149,031	$22,035			$171,066	$341,581
TOTAL	$326,730	$314,358	$39,535			$353,893	$680,623

HYBRID STRIPED BASS[5]

Progress Report for the Period
September 1, 2001 to August 31, 2003

NCRAC FUNDING LEVEL: $201,743 (September 1, 2001 to August 31, 2003)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
William C. Nelson	North Dakota State University	North Dakota
Industry Advisory Council Liaison:		
Forrest Williams	Bay Port Aquaculture, Bay Port	Michigan
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
David LaBomascus	Genesis, Inc., Cedar Rapids	Iowa

PROJECT OBJECTIVES

(1) Marketing

a. Investigate and document current and potential demand (prices and quantities) for hybrid striped bass (live and processed), clearly identifying consumer groups, processors, and distributors by location, seasonality of demand, size preferences, unique demand attributes, i.e., "healer fish" in Chinese culture, and impact of increased supplies on market prices of hybrid striped bass and competitive species.
b. Estimate the processing and distribution costs (supply chain costs and margins) to derive expected "farm gate live weight" prices as a function of producer and consumer locations.
c. Conduct limited taste testing on hybrid striped bass to determine the effect of different feed rations.
d. Develop a Web page that would be a component of the NCRAC Web site that would provide analysis results to clientele quickly and to allow easy updates.
e. Design and investigate willingness of hybrid striped bass producers to become a part of a current market information system.

(2) Compare phase III production parameters and feed costs of hybrid striped bass/sunshine bass (female white bass × male striped bass) in ponds and

[5]NCRAC has funded seven Hybrid Striped Bass projects. Termination reports for the first four projects are contained in the 1989-1996 Compendium Report; a project component termination report for the two research objectives of the fifth project is contained in the 1997-98 Annual Progress Report; and a termination report for the remaining objective of the fifth project as well as the objectives of the sixth project is contained in the 2000-01 Annual Progress Report. The first five projects were all chaired by Christopher C. Kohler and the sixth project was chaired by Joseph E. Morris. This progress report is for the seventh Hybrid Striped Bass project which is chaired by Christopher C. Kohler. It is a 3-year project that began September 1, 2001.

recirculating aquaculture systems using commercially available diets (32, 36, and 40% protein) in a minimum of two locations (three feed treatments/location), with 100 g ± 20 g (3.5 oz ± 0.7 oz) phase III fish (minimum of three replications/treatment), in ponds at least 0.4 ha (0.1 acre), with a stocking density of 7,413 fish/ha (3,000/acre), or in tanks at least 1,893 L/tank (500 gal/tank) with a 60 g/L (0.5 lb/gal) at harvest loading density. A need also exists to identify cost-effective, commercial available diets for phase III production.

ANTICIPATED BENEFITS

Success in the marketplace requires efficient production processes of products desired by consumers. Objective 1 of this project focuses on providing additional information to producers about the industry and market for their product. Better market information leads to better marketing decisions and increased revenue to the producer. The first three marketing objectives will provide a detailed picture of the current market conditions for hybrid striped bass while the last two objectives focus on providing a better system for future information flow and marketing decisions. The overall objective is to assist producers in improving their marketing decisions and thereby increasing revenue and profits.

The project for Objective 2 was designed to take laboratory-derived data from other funding sources, and use it in the production of hybrid striped bass on a larger scale. Thus, developing data that will be directly useful to producers of hybrid striped bass, including new dietary formulations that could be manufactured in the North Central Region (NCR). Full production characteristics will be developed that should provide a complete picture of production using new diets under environmental conditions in the NCR. The dietary formulations used in these studies will also be available for producers to take to their feed mills.

The studies will be conducted in replicated, commercially-simulated experimental designs. Feeds are typically the largest component of annual variable costs in aquaculture operations and any modification can improve overall farm production characteristics. More importantly, there are new formulations that can be manufactured in the NCR, yet those formulations have not been tested in larger scale pond production systems. This project will result in data that should be immediately useful in the NCR. These studies will also clearly demonstrate the commercial feasibility and potential for raising hybrid striped bass in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

All components of this objective are or will be undertaken by researchers at North Dakota State University (NDSU). They have made significant progress in regard to Sub-objectives 1a, 1b, and 1d. Background research on domestic and international aquaculture markets was conducted to gain knowledge on the general structure of the aquaculture industry. They have also begun to investigate and document the current and potential demand for hybrid striped bass as well as estimating the processing and distribution costs of this cultured animal. Their major effort and output to date has been in regard to sub-objective 1d—the development and creation of a hybrid striped bass Web page. This Web page can be found at http://ag.ansc.purdue.edu/aquanic/hsb/Index/Final%20Frontpage.htm and will be linked to the NCRAC Web.

Originally the Web page was to be more limited in scope. However, as information was being gathered for some of the other marketing sub-objectives, it was decided that this information would be more useful and accessible if it, too, was available on the Web. Therefore, a decision was made to expand the site and make it a very comprehensive collection of information for the hybrid striped bass industry. It also lends itself to periodical updating on a component by component basis without the expense of creating new hard copy publications. The content of the site is organized into eight major sections (Fish Information; Research; Producers; Links; Literature; Recipes; Contacts; and Videos/Presentations) which are listed on the home page. The home page will also have a link to something that is timely and of particular interest concerning hybrid striped bass. For example, the current home page contains a link to a PowerPoint file on "U.S. Production and Sales of Hybrid Striped Bass (1987-2002)."

OBJECTIVE 2

To produce phase III hybrid striped bass, researchers at Southern Illinois University-Carbondale (SIUC) obtained in June 2001, 10,000 phase II fish from Keo Fish Farm (Keo, Arkansas). Fish were stocked in floating vertical raceways (~8 m^3 [282 ft^3]) and reared at two densities (188 fish/m^3 [5.3 fish/ft^3] and 125 fish/m^3 [3.5 fish/ft^3). Fish with a mean starting weight of 0.7 g (0.02 oz) were fed a 40% crude protein diet to satiation for 121 days, with fish in the low-density treatment reaching a final mean weight of 160.0 g (5.6 oz), which was significantly larger than the 136.9 g (4.8 oz) final mean weight in the high-density treatment. Survival in the low-density treatment (81.1%) was significantly higher than the survival in the high-density treatment (73.8%). No significant differences occurred between treatments in terms of dissolved oxygen, total ammonia, un-ionized ammonia, or temperature. Temperature remained destratified inside the raceways throughout the growing period, allowing for cooler temperature profiles during the warmer months. Water temperature outside the raceways remained stratified throughout the summer and early fall.

Fish grown in the vertical floating raceways were subsequently stocked by SIUC researchers into 12, 0.04-ha (0.01-acre) earthen ponds supplied with continuous aeration at the SIUC Touch of Nature Aquaculture Research facility in April 2002. These phase III fish were stocked at a density of 6,177 fish/ha (2,500 fish/acre). There were four ponds randomly assigned for the three dietary treatments (crude protein levels of 32, 36, and 40%). Fish were fed once daily in the evening to apparent satiation using practical diets formulated at SIUC to conserve energy and milled by Farm Land/Land-O-Lakes Industries. The feeding trial was initiated May 2002 after determining the average initial weight (mean ± SE: 214 ± 5 g; 7.55 ± 0.18 oz) and total length (245 ± 1.6 mm; 9.64 ± 0.06 in).

Fish were harvested in November 2002 and two ponds (one each from the 32% and 36% protein diet) were omitted from statistical analysis due to heavy bird predation. Production rates were 3,149 ± 82 kg/ha/season (2,809 ± 73 lb/acre/season), 2,972 ± 373 kg/ha/season (2,651 ± 333 lb/acre/season), and 2,953 ± 142 kg/acre/season (2,634 ± 127 lb/acre/season) respective to low (32%), medium (36%), and high (40%) protein diets and were not statistically different. In addition, dress-out percentage and feed conversion ratios (~2.8:1) did not vary with diet. Production costs attributable to feed were $1.25, $1.38, and $1.41/kg gain for the 32, 36, and 40% protein feeds, respectively ($0.57, $0.63, and $0.64/lb gain).

To have additional phase-II fish for 2003 production, 4-day posthatch hybrid striped bass were obtained by SIUC from Keo Fish Farm in May 2002 and stocked at a rate of 375,000 fish/ha (151,760 fish/acre) in 15, 0.04-ha (0.1-acre) earthen ponds as described above, harvested in July 2002, and restocked at 25,000 fish/ha (10,117 fish/acre) for phase-II production in the same 15 ponds. Fish were fed a 40% crude protein diet manufactured by Nelson & Sons (South Murray, Utah) twice daily to satiation. Fish were harvested in mid-November 2002 and subsequently restocked into ponds for later use in the experimental recirculating aquaculture system in 2003.

Fish were harvested and transported to the SIUC indoor culture facility in July 2003. The fish were acclimated to the experimental recirculating aquaculture system for two weeks prior to the initiation of the experiment. During acclimatization, the fish were offered a floating trout feed (40% crude protein, 7.5 mm [0.3 in]) manufactured by Nelson & Sons (South Murray, Utah).

On July 25, 2003, following acclimatization, the fish were graded and randomly stocked at 200 fish/tank into12, 1,893-L (500-gal) fiberglass tanks that are part of a single recirculating system. The fish averaged 110 g (0.24 lb) in weight. They are being reared under continuous light (24-h photoperiod) and water temperature is maintained within 2° of 75°F (24°C) and stocked at 200 fish/tank. Fish are fed to apparent satiation twice daily and feed consumption is recorded. Water quality parameters are measured daily and fish will be harvested in late winter or early spring of 2004. Commercial diets manufactured by Nelson & Sons (South Murray, Utah) were used for the three treatments, 32, 36, and 40% protein.

Researchers at Purdue University (Purdue) developed three production diets for grow-out of hybrid striped bass. Those diets contained 32, 36, or 40% dietary crude protein, high levels of soybean meal, low levels of fish meal, and the essential amino acid profile determined optimal in previous laboratory studies. All three feeds were manufactured by a commercial feed mill, Nelson & Sons (South Murray, Utah), and the extruded diets shipped to Purdue for testing. Fish were acquired from Keo Fish Farms (Keo, Arkansas) in October 2001 before the project actually began and stocked into nine earthen 0.1-ha (0.25-acre) culture ponds in excess of 7,920 fish/ha (3,600 fish/acre) at the Purdue Aquaculture Research Laboratory. Three ponds per treatment (32, 36, and 40% crude protein) were randomly assigned. The fish were fed their respective diet once daily to apparent satiation beginning in April 2002. In March 2003 the ponds were seined to reduce the densities of the fish to 7,920 fish/ha (3,600 fish/acre). They were once again fed their respective diet once daily to apparent satiation. Final harvest will occur in late September or early October of 2003 after which final production data will determined.

WORK PLANNED

OBJECTIVE 1

NDSU researchers will continue to gather data and update the Web site that they developed during Year 2 as well as survey producers to determine the feasibility of an Internet-based market information cooperative.

OBJECTIVE 2

Researchers at SIUC will complete the phase III grow-out trial in their indoor recirculating system.

Researchers at Purdue will finalize their current feeding trial and conduct additional laboratory studies that will help define formulation strategies for hybrid striped bass. Unfortunately, the research they had planned with Genesis, Inc. in Cedar Rapids, Iowa will not be undertaken because that company went out of business in 2002.

IMPACTS

While the principal impact will be upon producers' profits, it is impossible to estimate the degree of the impact of the information generated and the effect of a market information cooperative at this time.

The production of hybrid striped bass as a food fish is rapidly developing as a viable industry in the Midwestern United States. For example, production of food-size hybrid striped bass in Illinois is approaching 90,720 kg (200,000 lb) in 2003. Results from the SIUC study further demonstrate the viability of rearing hybrid striped bass in ponds in at least the lower portion of the NCR. The indoor recirculating aquaculture system studies, once completed, should also demonstrate the feasibility of raising these fish in such systems. These results will also shed light on feeding and nutrition.

Feed represents the largest variable cost in intensive production of phase-III hybrid striped bass, with protein levels and sources having the greatest affect on feed cost. Developments in dietary formulations will result in new, modern diets that meet the unique nutritional requirements of this species, while reducing ammonia and carbon dioxide excretion. Further, these diets contain ingredients that are available in the NCR and that can be manufactured in the region.

Based on sampling of phase-III fish, SIUC researchers anticipate demonstrating the feasibility of raising hybrid striped bass to a size well in excess of the minimum marketable size of 680 g (1.5 lb). Moreover, SIUC researchers will be in a position to provide information that will facilitate decision making by phase III hybrid striped bass producers in the NCR with regard to the protein/nutrient density that optimizes production.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Hybrid Striped Bass activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-03	$201,743	$128,053				$128,053	$329,796
TOTAL	$201,743	$128,053				$128,053	$329,796

SUNFISH[6]

Progress Report for the Period
September 1, 1999 to August 31, 2003

NCRAC FUNDING LEVEL: $32,000 (September 1, 1999 to August 31, 2003)

PARTICIPANT:

Robert S. Hayward	University of Missouri-Columbia	Missouri
Industry Advisory Council Liaison:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborator:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri

PROJECT OBJECTIVE

Evaluate grading strategies to enhance grow out of F_1 hybrid sunfish (female green sunfish × male bluegill) in commercial systems to market size ($\geq$227 g; 0.5 lb), including the culture potential of discards.

ANTICIPATED BENEFITS

This study will indicate whether stocking the larger half (upper 50th percentile) of spring-available age-1 hybrid sunfish in ponds will result in higher growth rates and reduced grow-out times to food-market weights, versus when full size ranges of available fish are stocked. The study will also provide much needed information on the potential to rear hybrid sunfish to food-market weights within two years in mid-latitude ponds.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This study represents a field test of findings from a previous North Central Regional Aquaculture Center (NCRAC)-funded laboratory study wherein age-1 hybrid sunfish ranging in lengths from 8.2–10.2 cm (3.2–4.0 in) were held individually and reared with unrestricted feeding at 24.0°C (75.2°F) for 112 days. Laboratory results showed that age-1 fish that were initially larger consumed more food, grew faster, and had better feed conversion than counterparts that were initially smaller. The indication that poorer performing hybrid sunfish reveal themselves early on (by being smaller than same-age counterparts) suggested that stocking fish in the upper end of available size ranges may lead to faster growth and shorter grow-out times to food-market sizes. Also, by stocking upper-end, presumably better performing fish, size variation among individuals at harvest might be less (because of less disparate growth rates) than when full size ranges of available fish are stocked.

[6]NCRAC has funded five Sunfish projects. Termination reports for the first two projects, or components thereof, are contained in the 1989-1996 Compendium Report; a termination report for the third and fourth projects is contained in the 1998-99 Annual Progress Report; and a termination report for one of the two objectives of the fifth project is contained in the 2001-02 Annual Progress Report. This progress report is for the second objective of the fifth Sunfish project which is chaired by Robert S. Hayward. It was originally a 2-year project that began September 1, 1999 but was lengthened for no additional cost.

In April 2000, age-1 hybrid sunfish were collected from a single production pond at Flower's Aquaculture in Dexter, Missouri and graded into two size groups: smaller half (mean length = 4.1 cm [1.6 in], length range = 3.3–5.3 cm [1.3–2.1 in]; mean weight = 1.03 g [0.04 oz] wet weight), and larger half (mean length = 6.3 cm [2.5 in], length range = 5.4–7.7 cm [1.2–3.0 in]; mean weight = 3.94 g [0.14 oz] wet weight). The fish were transported to Harrison's Fish Farm in Hurdland, Missouri on April 17, 2000 and stocked into 7, 0.20-ha (0.5-acre) ponds. Three ponds (designated "L") received only larger-half fish (3,231 fish/pond), three ponds (designated "S-L") received 3,000 smaller-half plus 3,000 larger-half fish, and one pond (designated "S") received 14,000 smaller-half fish. Stocking densities (dry biomass/surface area) were matched in the ponds receiving large only and large plus small fish; stocking density was lower in the pond receiving only small fish.

Fish were fed twice daily with a floating commercial diet. Partial seining of each pond was done six times from 1 month post-stocking through early October 2001 (approximately every 3 months) to monitor hybrid sunfish weights and lengths; samples of 30–50 fish from each pond were measured and weighed on each outing. In January 2001, a broken drain pipe caused the loss of all fish in one of the three "L" ponds. In June 2001 it was decided that fish biomass in all ponds had become too high to allow desired growth rates. Therefore, to improve growth conditions, an attempt was made to remove all hybrid sunfish from each pond by multiple seine hauls. Only the larger 33% (by length) were re-stocked; the harvested smaller fish were sold by the producer.

The pond experiment was ended in June 2002, 26 months after the hybrid sunfish were stocked. Overall, the 26-month pond study provided further evidence that stocking larger-end, age-1 hybrid sunfish will lead to higher growth rates with less development of size variation. It is expected that there would be similar benefits from using upper-end age-1 hybrid sunfish when rearing these fish in indoor recirculating tanks as well. It is emphasized that larger fish were likely produced in the ponds that were stocked by upper-end fish, not simply because the fish were larger to begin with, but because they grew faster than counterparts that were initially smaller. These findings also provide much needed information on time periods required to rear to food-market sizes in ponds. Even when stocking larger-end, age-1, upper quartile fish reached only 65% of the minimum food-market weight of 227 g (0.5 lb). This finding suggests that for middle-latitude ponds, at least three years of rearing is probably needed to get significant numbers of hybrid sunfish to food-market sizes.

In addition to the pond experiment, several laboratory studies were conducted at the University of Missouri-Columbia (UMC) from 2001 through 2003 supported, in part, by NCRAC funding. Though not described in the original Sunfish project outline, the results from one of those studies is described here because it relates to and holds potentially important implications for the broad objective of developing approaches to rear Lepomid sunfish to food-market sizes within two grow-out years.

UMC researchers conducted a study of bluegill growth in indoor tanks with the objective of comparing growth rates towards food-market weight ($\geq$227 g; 0.5 lb) between tanks with bluegill sex-ratios close to 1:1, and those with higher proportions of male fish in a true culture setting. The basis for this study was the earlier finding at UMC (using individually-held fish) that bluegill have substantially greater growth capacity than hybrid bluegill despite the fact that the hybrids grow faster in ponds. Follow-up work showed that the male bluegill's growth capacity is markedly greater than that of the female bluegill. Although sexually-dimorphic growth is known to exist in Lepomid sunfish, the extent of the male bluegill's marked growth capacity advantage over female bluegill is not well known, and exceeds the difference between male and female hybrids.

The capacity to effectively size-separate male and female bluegill once fish reach about 7.6 cm (3.0 in) has been developed at UMC. This approach was used in the present study to form bluegill groups with different sex ratios. However, the UMC researchers did not have enough project funds to secure an adequate number of bluegill to form groups comprising a very high percentage of males.

Three hundred bluegill of mean weight 16.3 g (0.6 oz) were stocked into each of four 1,000-L (264-gal) tanks. The two mixed-sex tanks contained 56.7 and 50.7% male bluegill while the two tanks intended to have higher male sex ratios had 69.9 and 66.3% males. Fish were reared at 25°C (77°F) and fed 1.5% of body mass daily via seven feedings between 06:00 and 08:00 with an automatic feeder. The feed was Aquamax® Grower 400 (45% crude protein). High water quality was maintained by siphoning (twice weekly) and water replacement (33% weekly). Fish were reared under a summer-like photo-regime (14-h light/10-h dark) for 234 days (7.8 months) from January 10 to August 29, 2003. On a monthly basis, 30–50 fish were sampled from each tank and individually measured for length and weight. All mortalities were recorded.

Combining across the four tanks and both sexes, bluegill reached 50th, 75th, and 100th percentiles of weight that were equivalent to 22, 40, and 86% of the low-end food market weight of 227 g (0.5 lb) within 7.8 months. However, mean growth rates of male and female bluegill across the four tanks were 0.30 g/day (0.010 oz/day) and 0.09 g/day (0.003 oz/day), respectively, and were significantly different (paired t-test; $P<0.05$). After 7.8 months of rearing, 50th, 75th, and 100th percentile weights of male bluegill were 35, 49, and 86% of 227 g (0.,5 lb), while those for female bluegill were 12, 19, and 54%. In a previous 26-month study where hybrid bluegill (predominantly male fish) were provided commercial feed in northern Missouri ponds, fish in the 87.5th percentile of weight reached only 65% of 227 g (0.5 lb). In contrast, male bluegill in the 87.5th percentile of weight in the present study reached 67.6% of 227 g (0.5 lb) after only 7.8 months of tank rearing.

Despite relatively modest differences in sex ratios between the control tanks containing mixed sex ratios of bluegill (50.7 and 56.7% male fish) and treatment tanks (66.3 and 69.9% male fish), mean weight gain of fish in the treatment tanks was significantly higher than in the control tanks (paired t-test; $P<0.05$) by approximately 10 g (0.35 oz). Overall, study results indicate that the capacity to rear sunfish to food-market sizes within two years of grow out is much greater when predominantly male bluegill are grown in indoor tanks, relative to pond rearing hybrid bluegill in ponds in the middle latitudes of the Midwest region. Studies where much higher percentages of male bluegill are reared in indoor tanks are warranted as the present results suggest that even higher growth rates than those observed can be achieved. UMC researchers note that the mean mortality rate across the four tanks was only 5.8%; however, feed conversion ratios averaged only 2.74. It is believed that this low feed conversion was related to high social costs among bluegill in tanks where subordinated fish ate relatively little. Developing methods to reduce agonistic social interaction among bluegill in tanks may be important both for improving feed conversion and growth rates.

WORK PLANNED
A termination report will be produced in 2003.

IMPACTS

- The work at UMC, based on rough projections of growth rates, indicate that male bluegill possess the inherent capacity to grow to food-market weights within two years while female bluegill and both sexes of the hybrid sunfish fall substantially short of this benchmark even under the best of growing conditions. This data provide evidence that efforts to rear *Lepomis* species to food-market weights within the established two-year benchmark for grow out, should focus on male bluegill.
- The pond study also indicates whether size grading of hybrid sunfish will effectively reduce grow-out times to food-market size. These results should add significantly to a scant data base that will indicate the feasibility of rearing hybrid sunfish in food-market aquaculture.
- The laboratory study indicates that much reduced growth times to food-market weights would be possible by rearing male bluegill and this finding may substantially improve the economic feasibility of rearing sunfish for food markets.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See the Appendix for a cumulative output for all NCRAC-funded Sunfish activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-03	$32,000	$10,765				$10,765	$42,765
TOTAL	$32,000	$10,765				$10,765	$42,765

WASTES/EFFLUENTS[7]

Progress Report for the Period
September 1, 2001 to August 31, 2003

NCRAC FUNDING LEVEL: $149,280 (September 1, 2001 to August 31, 2003)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Douglas J. Reinemann	University of Wisconsin-Madison	Wisconsin
Robert C. Summerfelt	Iowa State University	Iowa
Steven E. Yeo	University of Wisconsin-Milwaukee	Wisconsin
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Non-Funded Collaborators:		
Michael Becker	Odbek Industries, Inc., St. Paul	Minnesota
Von Byrd	USDA Forest Products Laboratory, Madison	Wisconsin
Chuck Ehlers	Ehlers Enterprises, Manning	Iowa
Jae Park	University of Wisconsin-Madison	Wisconsin
Mark Raabe	REM Engineering, LLC, Evansville	Wisconsin
Todd Rogers	Odbek Industries, Inc., St. Paul	Minnesota
Roger Rowell	USDA Forest Products Laboratory, Madison	Wisconsin

PROJECT OBJECTIVES

(1) Document the fate of aquaculture waste components (phosphorus, nitrogen, solids) relative to feed input into traditional and newly designed aquaculture systems.

(2) Evaluate the technical and economic feasibility of rapid solids removal/recovery appropriate for new aquaculture facility designs.

(3) Demonstrate economically sound processing methods for beneficial use of aquaculture waste.

(4) Provide workshops and fact sheets that address best management practices (BMPs) for waste control.

ANTICIPATED BENEFITS

OBJECTIVE 1

Traditional flowing water culture systems (i.e., raceways) produce a large volume of

[7]NCRAC has funded three Wastes/Effluents projects. The termination report for the first project is contained in the 1989-1996 Compendium Report; a termination report for one of the two objectives of the second project is contained in the 1998-99 Annual Progress Report, and a termination report for other objective of the second project, which was chaired by Fred P. Binkowski, is contained in the 1999-00 Annual Progress Report. This progress report is for the third Wastes/Effluents project which is chaired by Robert C. Summerfelt. It is a 3-year project that began September 1, 2001.

effluent with relatively dilute waste concentration, whereas, recycle aquaculture systems produce a small volume of effluent with concentrated wastes, typically rich in organic solids, which gives it a high biochemical oxygen demand (BOD) and nutrients (e.g., nitrogen and phosphorus), which are the cause of eutrophication in surface waters. However, a small volume of concentrated wastes produced in recycle aquaculture systems is easier to treat than a high volume of dilute wastes in effluents from flow-through raceway systems, given that it may be treated by a septic tank system and land application used for disposal of the septic tank sludge.

The results of the study being conducted by researchers at Iowa State University (ISU) at a large state-of-the-art commercial recycle aquaculture system will characterize a unique fish hatchery wastewater and solids disposal system that has no surface discharge to public waters and which produces a by-product with some market value. The facility has a septic tank to capture solids and nutrients from the effluent of the culture system. The information obtained from this system may be used to support the development of best management strategies for the category of recirculating aquaculture facilities to meet the final U.S. Environmental Protection Agency (USEPA) guidelines and standards that are to be issued by June 2004.

OBJECTIVE 2

Studies being conducted by ISU at a large state-of-the-art commercial recycle aquaculture system should lead to cost-effective methods for rapid removal of waste feed and fish feces from culture systems to maintain good water quality for the fish, to prevent leaching of nutrients from the solids, and the breakdown of solids to particle sizes smaller than can be efficiently removed by practical filtration.

University of Wisconsin-Madison (UW-Madison) reseachers are evaluating the use of natural wood fibers as a filter material for aquaculture. The use of these natural fiber filters will greatly reduce the amount and concentration of organic solids that are discharged into the environment from aquaculture raceways and ponds. The retention of solids by these filters will significantly reduce the amount of nutrients entering the receiving stream, resulting in improved water quality downstream from existing fish culture facilities.

Many natural fibers have fundamental properties that make them ideal for use as a filter material. After minimal processing, the surface area of many fibers is very large per unit area. They are inexpensive, renewable, and biodegradable.

This technology can be integrated into the design of new raceways and ponds. However, it also provides an affordable option to aquaculturists who must reduce the discharge of solids and nutrients from existing raceways and ponds. Disposable natural fiber filters can be made inexpensively from a variety of wood and plant fibers. Thus, the application of natural fiber filters to aquaculture will provide economic opportunities to the agriculture industry to market low value fiber or waste fiber. One additional benefit to this technology is that spent fibers can be composted and used as a soil amendment for agriculture.

OBJECTIVE 3

University of Wisconsin-Milwaukee (UW-Milwaukee) researchers at the Great Lakes WATER Institute are evaluating vermiculture and vermicomposting as a beneficial use of biosolids from aquaculture waste. For small-scale recycle aquaculture system operations, typical of some of the systems currently operated in the North Central Region (NCR), integrating these methods with fish production offers an appropriately scaled and on-site means of converting solid waste to salable baitworms and worm castings that could be niche marketed to fishermen or organic gardeners. Future expansion of regional aquaculture requires lowered water usage and reduction of potentially harmful waste discharge. Vermicomposting has the potential to increase the cost effectiveness of recycle aquaculture systems operation by converting the recovered waste solids into beneficial reusable and salable by-products. Used along with aquaponic plant production to recover dissolved nutrients, more fully integrated, sustainable, and cost-effective rearing systems may be developed that will overcome current constraints and allow further industry development.

Worm and worm compost production would not involve the high energy inputs for pumping or lighting that are necessary for integrating aquaponics with recycle aquaculture system operation. Depending on further examination of costs and the marketability of worms and worm-produced by-products, these techniques could provide favorable alternatives to disposal by diversion of aquaculture solids to public sewage treatment facilities that lessens the quality of the sludge through mixture with a variety of municipal and industrial waste. Worm composting provides a superior form of stabilized compost that is more suitable and valuable for potted plant or smaller scale gardening users than liquid septic storage sludge that is now typically spread thinly in outdoor field application situations. Diversion of biosolids to worm composting would lighten the load to on-site septic facilities, reducing the size of septic storage facilities needed, and perhaps increasing the maintenance intervals. Stabilized worm compost can be readily stored compared to liquid sludge and when diverted to gardening and indoor planting uses could assist in avoiding the seasonal climatic limitations on land application.

OBJECTIVE 4

On September 12, 2002, the USEPA released proposed rules for effluent limitations guidelines and standards for the concentrated aquatic animal production category under authority of the Clean Water Act. The final USEPA rules are to be released by June 2004. Work from this objective will help producers better understand the proposed rules and provide guidance for development of BMPs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Researchers at ISU have been monitoring the mass balance of nutrient inputs in feed and water and outputs (phosphorus, nitrogen, and solids) from a large state-of-the-art commercial recycle aquaculture system in west-central Iowa (Ehler Enterprises in Manning) for the last two years. This facility has five dual-drain tanks, which have sidewall and center drains. About 78% of the effluent from the tanks leaves via the sidewall drain and goes to a sump and then to the biofilter. Flow from the center drain passes through an external triple standpipe and then to a drum filter. The drum filter, equipped with a 60-µm mesh microscreen, receives the center drain flow of all five tanks. The triple standpipe is an external cylindrical tank with three standpipes of different heights. The shortest standpipe (11.2 cm; 4.4 in) receives the flow from the center drain of the culture tank. A standpipe of intermediate height sets the height of the water level in the culture tank and overflow into this standpipe flows to the drum filter. The third, tallest, standpipe, never overflows, but when manually pulled once daily for 10 seconds, it drains the accumulated solids from below the shortest standpipe. The triple standpipe functions like a swirl separator to allow rapid removal of heavier solids that settle below the shortest standpipe. These solids are diverted to a septic tank. The overflow from the septic tank effluent goes to a drain field, not directly to a receiving stream. During the first year of study, the septic tank contents were pumped out and land applied, but in the second year the septic tank slurry was transferred to a concrete holding tank (former waste pit of a hog confinement facility) to air dry. The producer found a nursery that bought the dried septic tank solids (dried fish manure) for use as a fertilizer and soil amendment.

Nutrients and solids have been measured in both the recycle system as well as the septic tank. Water quality assurance methods were developed with written procedures, work instructions, and record keeping protocols. Quality control included measurements of concentration recovery of spiked samples (known addition method) for every parameter on every sample date.

Solids accumulation in the septic tank were analyzed from samples of the slurry pumped from the septic tank. Effluent from the septic tank was collected with an autosampler over 3- and 12-h intervals, but because there was not a significant difference between values for 3- and 12-h collections, the 3-h sample is to be used in future samples. Septic tank sludge is collected when the septic tank is drained. The normal schedule for septic tank draining and pump out of sludge was twice per year, but it will be more frequent during the study to provide information on septic tank treatment of the fish hatchery waste. Septic tank sludge (a slurry) is surface applied to 0.8 ha (2.0 acres) of crop land used for soybeans.

From July 22 through August 29, 2002, six sets of samples were obtained to measure inputs of total solids and nutrients from the freshwater supply and the feed, and outputs of solids and nutrients from the culture system to the septic tank, and from the septic tank effluents and solids. In this interval, the fish feed input averaged 16.2 kg/day (35.7 lb/day) (dry weight basis), 1.27 kg (2.80 lb) total nitrogen (TN), and 0.23 kg (0.51 lb) total phosphorus (TP). The combined effluent from the drum filter and the triple standpipe to the septic tank was 9.13 kg/day (20.13 lb/day) total suspended solids (TSS), 0.98 kg/day (2.16 lb/day) TN, and 0.09 kg/day (0.20 lb/day) TP. TP in the effluent to the septic tank was 5.6 g TP/kg of feed per day (0.090 oz/lb), which compares with published values of 5.0–5.9 g TP/kg feed per day (0.080–0.094 oz/lb).

TP leaving the septic tank to the tile drainage field was 3.1 g TP/kg of feed per day (0.05 oz/lb), implying that 55% of the TP input to the septic tank leaves the septic tank in the fluid flow and 45% is retained in the solids portion of the septic tank. There is no other published literature with this information. Including a septic tank in the waste treatment process will reduce TP output to surface water by about half of the output from the culture system. Because it is well known that phosphorus is strongly attached to soil, the distribution of the septic tank effluent into septic tank drainage tile will eliminate nearly half of the TP effluent problem.

A slurry of septic tank contents that accumulated in the 90-day interval of July through September contained an average of 4,750 mg/L (ppm) TSS and 112 mg/L (ppm) TP. Based on input and output measurements, an average of 91% of the TSS input to the septic tank was metabolized by the septic tank; only 6% left the septic tank to the septic tank drainage field and 3%

was present in the slurry pumped out from the septic tank after the 90-day interval. The TSS in the effluent from the septic tank to the field tile was 51 mg/L (ppm), comparable to a range of 45–65 mg/L (ppm) for household septic systems.

The TN content entering the septic tank averaged 0.98 kg/day (0.035 oz/day) and the output in the effluent from the septic tank averaged 0.80 kg/day (0.028 oz/day), indicating that 82% the nitrogen entering the septic tank leaves in the effluent to the field tile.

Research in Year 2 was divided into four intervals for data compilation and analysis: interval 1, 61 days (October 10-December 10, 2002), interval 2, 160 days (December 10, 2002-May 21, 2003), interval 3, 27 days (May 21-June 17, 2003), and interval 4, 28 days (June 17-July 15, 2003). Only data from interval 4 is included because the septic tank was drained at the beginning and end of that interval, which allowed for calculation of mass balance of nutrients and solids. In this interval, the operator was carrying out polyculture of hybrid striped bass, largemouth bass, rainbow trout, and walleye (two tanks). Standing stock of fish averaged 4,654 kg (10,239 lb), of which 36% was rainbow trout, 35% walleye, 20% hybrid striped bass, and 9% largemouth bass. Feeding rate varied by species; it was much lower for trout and walleye because they were ready for market, but the average for all species was 3% of the body weight per day.

The culture system consisted of five culture tanks, each 39.2 m^3 (10,356 gal), which comprised 78.5% of total system volume (250.0 m^3; 66,043 gal), and other system components—triple standpipes, sidewall drains, drum filter, sump, biofilter, degassing tower, low head oxygenator, and all of the supply and drain pipes—made up 21.5% of total system volume. Total volume of a recycle aquaculture system (tanks and other) is about 1.3× the volume of the culture tanks.

In interval 4, the average daily inflow (3.41 Lpm; 0.9 gpm) provided the culture tanks with an exchange of 0.9 tank volume per hour, which was sufficient to maintain suitable water quality. In this interval, daily water use was 2.0% of total system volume, which is considerably less than the 5–10% reported in the literature for most recycle systems. Daily inflow was only that needed to replace water loss—often called make-up water—to backwash the drum filter and flush the triple standpipes. The major sources of water loss (85.6% of total) were from the drum filter backwash (54.9%), and the triple standpipe (30.2%). Other sources of water loss were from evaporation and several miscellaneous sources.

Nutrient inputs (nitrogen and phosphorus) expressed in mass per day, were from nutrient content of the inflowing water and fish feed. Nutrients and solids were measured in the effluent from the culture building to the septic tank, effluent (output) of the septic tank to the septic tank drainage field, from samples of the slurry pumped from the septic tank, and of the dried matter from the septic tank slurry.

The inflowing water added 0.0043 kg/day (0.15 oz/day) TN and 0.0026 kg/day (0.09 oz/day) TP, which is quite trivial relative to the nitrogen and phosphorus added in the feed; inflowing water added 0.3% of nitrogen and 0.8% of phosphorus compared with the feed. These inputs were subtracted from nutrient outputs to the septic tank to isolate nutrient inputs from the feed. The nitrogen content of the dry weight of the three kinds of feed utilized was 8.1%. The average daily input of feed (all tanks combined) was 13.6 kg/day dry weight (30.0

lb/day). The nitrogen addition from the feed was 1.6 kg/day (3.5 lb/day) for interval 4. Nitrogen (kg dry weight per day) in the effluent from the culture building to the septic tank (0.59 kg/day; 1.3 lb/day) was 36.7% of the nitrogen in the feed. Total nitrogen in the septic tank effluent going to the septic tank drainage field was 17.9 g/kg (ppt) feed fed, or 15% of the nitrogen fed. Based upon the concentration of nitrogen in the effluent from the septic tank, the septic tank removed 59.1% of the nitrogen inputs.

The TN content entering the septic tank averaged 0.59 kg/day (1.3 lb/day) and the output in the effluent from the septic tank averaged 0.24 kg/day (0.5 lb/day), indicating that 40.9% of the nitrogen entering the septic tank leaves in the effluent to the field tile, but it also means that 59.1% was removed during residence in the septic tank.

At the end of interval 4, the septic tank was pumped out and the slurry was analyzed for TN, TP, BOD, and TSS. The results were 828.7 mg/L (ppm) nitrogen, 343.9 mg/L (ppm) phosphorus, 1,060 mg O_2/L (ppm) BOD, and 13,700 mg/L (ppm) TSS. The slurry was dried in an empty concrete tank for 28 days. The dried sludge contained 12.8% moisture, 3.16% nitrogen, and 4.8% phosphorus. The dried sludge (dried fish manure) was sold to a nursery.

The weighted average phosphorus content of the three kinds of feed was 1.64% of dry weight. The phosphorus added from the fish feed was 0.32 kg/day (0.71 lb/day) for interval 4. Total phosphorus (mass dry weight per day) in the effluent from the culture building to the septic tank (0.28 kg/day; 0.62 lb/day) was 86% of the phosphorus in the feed. Total phosphorus in the septic tank effluent to the septic tank drainage field was 0.13 kg/day (0.29 lb/day). The inputs of total phosphorus to the drainage field were 46.8% of total phosphorus entering the septic tank. Based on the concentration of phosphorus entering (0.28 kg/day; 0.62 lb/day) and leaving the septic tank (0.13 kg/day; 0.29 lb/day), the septic tank removed 53.2% of the phosphorus inputs to the tank. The TP content of the 4.54 m^3 (1,200 gal) of slurry pumped from the septic tank after a 28-day culture interval was 1.56 kg (3.44 lb). The slurry was dried (now a fish manure) in a separate tank and analyzed for TP. The TP was 48 g/kg (ppt) dry weight.

The monthly average TSS output from the culture building to the septic tank was 517 mg/L (ppm), which was 17.2× the proposed 30 mg/L (ppm) TSS monthly average requirements for a recirculating system with more than 45,300 kg (100,000 lb) production. The septic tank removed 81% of the received TSS input to the tank. Only 19% of the TSS entering the septic tank left the septic tank effluent to the septic tank drainage field. The TSS in the effluent from the septic tank to the field tile was 240 mg/L (ppm), much higher than the USEPA proposed 30 mg/L (ppm) limit. Paradoxically, the proposed USEPA TSS limit is about half that of the range in TSS of 45–65 mg/L (ppm) for household septic systems.

OBJECTIVE 2

ISU researchers measured rapid solids removal from the culture tank effluent by the triple standpipe and drum filter. The dual-drain tank design had two discharges; 78% from the sidewall drain and 22% from the center drain. The center drain carried most of the suspended solids from the culture tank to the triple standpipe from which most of the flow went to the drum filter. A small flow of heavy solids was diverted to the septic tank by manually pulling the triple standpipe for 10 seconds daily.

The drum filter removed 26% (1.62 kg/day; 3.57 lb/day) and the triple standpipe removed 74% (4.53 kg/day; 9.99 lb/day) of the total quantity of solids (TSS) in the effluent from the center drain of the culture tank. The drum filer removed 55% (0.32 kg/day; 0.71 lb/day) of the TN, but only 38% (0.11 kg/day; 0.24 lb/day) of TP. Conversely, the triple standpipe removed 62% (0.18 kg/day; 0.40 lb/day) of TP but 45% (0.27 kg/day; 0.59 lb/day) of TN. Most of the TP was associated with the solids, but less so for TN. In the 10 seconds the triple standpipe was being drained, it removed solids stored below the shortest standpipe as well as some solids that are deposited in the lateral pipe from the center drain of the culture tank to the triple standpipe. The storage of solids in the bottom standpipe accounted for 96.2% of the concentration of TSS in the effluent of the triple standpipe, 56% of the TN, and 84.3% of the TP. Thus, accumulated solids in the drainpipe from the center drain were minimal, demonstrating that the triple standpipe reduces the load on the drum filter.

The goal of UW-Madison studies is to evaluate the feasibility of using wood fiber filters to capture solids from raceway and pond effluents. Prior to designing the fiber filters, information on the particle size of solids in raceway and pond effluents was needed. The particle size of three types of effluents was characterized as follows. The first was effluent from fingerling production ponds at the Lake Mills State Fish Hatchery (LMSFH). The effluent from the final 5% of the water was sampled during pond draining, because previous studies have shown that this portion of the effluent contains the highest concentration of solids. The second effluent characterized was from coho salmon production raceways at the LMSFH collected during “sweep” cleaning (a commonly used method to clean raceways). And the third was effluent from coho salmon production raceways at the LMSFH collected during “pump” cleaning (another commonly used method to clean raceways).

A small-scale filter box (designed for a flow rate of 4.0-6.0 Lpm [1.1–1.6 gpm]) was designed and built by UW-Madison researchers and engineers from the U.S. Department of Agriculture Forest Products Laboratory (FPL). This box was designed to accept 4–6 filters in a series flow design. Initial studies focused on flow dynamics, i.e., to minimize problems related to overflow and filter bypass. Once these problems were resolved, a set of graded Nytex® screens was installed to measure particle size and distribution. The results indicate that pond effluent contained a higher percentage of small particles than raceway effluent. Approximately 60% of solids from pond effluent, and 75% of solids from “swept” or “pumped” raceway effluent were retained by a 75 µm screen. According to FPL engineers, these data suggested that it should be possible to design wood fiber filters to retain a high percentage of solids and at the same time permit high flow rates through the filters.

Three types of fiber filters were then manufactured: “random,” made from 28% kenaf, 28% jute, 28% flax, 10% aspen, and 6% binder; “DW I,” made from 90% juniper and 10% binder; and “DW II,” made from 65% juniper, 15% aspen, 10% alfalfa, and 10% binder. Preliminary studies showed that all three filter types were effective at retaining solids from aquaculture effluents. In repeated tests using pond effluent (which contains smaller particles, in general, than raceway effluent), three random and DW I filters in a series retained more than 70% of the solids.

Findings on flow rates through the filters have shown that fiber filters can be practically designed to accommodate flow rates typically associated with pump cleaning of large scale raceways (60–200 Lpm; 16–53 gpm). Fiber filters capable of effectively removing solids from pond effluent can be designed, but the large surface area required to permit the extremely high flow rates associated with pond draining (>1,500 Lpm; 396 gpm) may make the application of fiber filters for pond effluent less feasible than for raceway effluent. Therefore, the remainder of the research will focus on the retention of solids from raceway effluents. Construction of a large-scale filter box capable of handling flows of 60–200 Lpm (16–53 gpm) has been recently completed.

OBJECTIVE 3

UW-Milwaukee scientists investigated processing methods for beneficial use of aquaculture waste. Their work is categorized into two sub-objectives.

Sub-objective A: One component of their research is to recover and partially dewater biosolids from intensive yellow perch aquaculture for use as a feedstock for vermicomposting using red worms and warmer-temperature tolerant “cultured” nightcrawlers. Back-flushed waste solids from a bead filter/clarifier of UW-Milwaukee’s 25-m^3 (6,604-gal) recycle aquaculture system, and to a lesser extent, some solids from a 3.3-m^3 (872-gal) circular flow-through tank of yellow perch fingerlings was obtained for use as worm food. A graduated conical-bottomed 560-L (148-gal) tank was used to separate the solids by settling from the remaining wastewater. The daily amount of sludge recovered from the bead filter varied widely with a mean volume of 48 L (13 gal), a range of 254 L (67 gal), and a modal value of 57 L (15 gal).

From January through October 8, 2002, about 973 kg (2,145 lb) dried weight of commercial fish feed was used to feed the perch in the recycle aquaculture system. During that same period, an accumulated total of 9.6 m^3 (2,536 gal) of settled sludge material (336 kg [741 lb] dried weight) was recovered from the bead filter back washings. This recovered sludge is about equivalent to 35% of the dried weight of the fish food (973 kg; 2,145 lb) used to grow out the approximately 10,000 perch fingerlings in the recycle aquaculture system during the 259-day period of operation. The bead filter sludge also contained some microbial floc and possibly small amounts of sand from the biofilter. In mid-December 2002 the recycle aquaculture system was restocked with perch fingerlings for another grow-out cycle (257 days of operation through August 31, 2003). During this period biosolids from the bead clarifier were again recovered. In this time period, a total of 14.4 m^3 (3,813 gal) of settled sludge was collected which was potentially available for use as worm food. This recovered amount was again equivalent to 35% of the dry weight of the fish food (1,460 kg; 3,219 lb) used during that period.

Sub-objective B: This component of the research is to propagate worm stocks using continuous composting bins utilizing bead filter sludge as food. Seed stocks were obtained of two species of earthworms with recognized potential for vermicomposting of organic materials: “cultured” nightcrawlers, *Eudrilus eugeniae*, (about 400 totaling 0.384 kg [0.847 lb]) and red worms, *Eisenia foetida*, (about 500 totaling 0.081 kg [0.179 lb]). In January 2002, these worm stocks were introduced into separate commercial continuous-vermicomposting bins. The surface area of each bin was 0.66 m^2 (7.10 ft^2) and contained 75 kg (165 lb) of initial bedding material that ranged in depth between 10–20 cm (3.9–7.9 in). Draining the sludge through the worm bedding dewatered the bead filter sludge. The majority of the solids from the bead filter sludge were retained in the upper layer of worm bedding and excess water dripped by gravity through the bed and collected in a drip pan. Feedings of settled sludge were measured volumetrically and poured from a 3.0-L (0.8-gal) graduated pitcher. Sludge feedings were applied in thin layers to cover only a portion of the bedding surface to insure that the worms could find a refuge from extreme conditions. Additional food was added when the previously added material had been worked over by the worm stocks. Accumulation of unused food was avoided to prevent anaerobic conditions, odor problems, and adversely high temperature conditions in the beds.

Worm populations in the bins were sampled at 2, 9, 14, and 23 weeks after stocking. Both species of worms prospered when fed the yellow perch recycle aquaculture system bead filter backwash sludge. Reproduction and cocoon deposition were observed in the first few weeks. The estimated worm initial stocking density (% by weight) in the bedding was 0.1% for the red worms and 0.5% for the nightcrawlers. The red worm bin population tended to increase steadily over the 23-week period both in terms of percent worms by weight (0.1–2.6%) and estimated number of worms (500 to ~13,000) in the bin. The nightcrawlers fluctuated in percent worm density by weight (range 0.5–6.4%). Nightcrawler density increased to 4.6% due to rapid initial growth, but then decreased as the larger older individuals died off gradually through the first nine weeks and were replaced by an abundant cohort of young worms after 42–48 days. In the nine-week sample, worm density by weight (1.9%) was less than half of what it was at two weeks, while the estimated number of worms in the bin had gone from an original 400 to approximately 12,000. By 14 weeks, the nightcrawler bin had regained high worm density by weight (6.4%) and estimated numbers appeared to remain around 13,000. However, by 23 weeks the worm sizes were mixed and not as clearly dominated by a single cohort in both numbers (~4,000) and density by weight (1.8%). Variation between samples on a given sampling date was high and handpicking subsamples was laborious. It is difficult to obtain accurate inventory of worm stocks in continuous batch culture in order to predict of the numbers of harvestable bait-size worms.

From January through September 2002, the worms were fed a total of 837 L (221 gal) of sludge. Individual feedings were generally in 3.0 L (0.8 gal) increments and varied from 0–18 L (0–4.8 gal) per bin on a given date. Following the harvest of the perch at the end of September 2002, through mid-December 2002 , the recycle aquaculture system was idle and the worm colonies were maintained using Purina worm chow. Once the 2003 perch production cycle of the UW-Milwaukee recycle aquaculture system was restarted in late December 2002 through October 2003, the worm bins were again maintained by feeding bead filter sludge. In that period, a total of 495 L (130 gal) of sludge was fed to the worms in the continuous compost bins.

The amount of recovered sludge from the recycle aquaculture system proved to be far greater than the capacity of these composters to accept the waste without creating undesirable bedding conditions and odor problems. Observation of the worms feeding on a thin layer of sludge (3–6 L) applied to each bin (0.66 m^2 or 7.10 ft^2) and covered with a light covering of soil, indicated that when sufficient worm stocks are present the food layer could be worked over in 3–4 days at which time more sludge could be applied. Applying sludge at a rate similar to that used for these composting bins (approximately 4.5–9 L/m^2 [0.11–0.22 gal/ft^2] at 4-day intervals), a worm bed of 25–50 m^2

(269–538 ft^2) could be readily supported at the modal level of sludge production.

Although the continuous vermicompost bins with mixed generations of worms would be suitable for compost production and waste recycling, for vermiculture of appropriately sized baitworms an approach that separates cohorts of worms by age and size would insure better inventory control, and avoid problems with trying to separate harvestable worms from the numerous smaller sized worms. At a commercial vermiculture operation in Racine, Wisconsin cultured nightcrawlers are grown in plastic pails (approximately10.0 L [2.6 gal] capacity) with ventilation holes punched into the upper rim. At about two-week intervals the worms are separated from the cocoons and fed a formulated commercial diet. Use of modular bins and a cohort separation management strategy is advantageous for inventory control in an operation intending to produce predictable numbers of harvestable bait-sized worms. Under UW-Milwaukee conditions, the smaller sized bed of the modular pails tended to dry more easily and required closer monitoring than the larger continuous composting beds. Perhaps a hybrid rearing scheme using the continuous composting bed as the principle waste processing method and using the modular bins to achieve the final rapid growth and fattening of worms (from the continuous composters where growth is slowed due to high density) to bait size with several weeks growth under less dense conditions would be most advantageous for recycle aquaculture waste recycling.

In the summer of 2002 UW-Milwaukee researchers compared bead filter sludge as a foodstuff for vermicomposting/vermiculture to a commercial worm diet. The influence of the addition of hardwood sawdust and shredded paper as worm bedding additives were also examined. This research was done with the assistance of an undergraduate participant in the National Science Foundation "Research Experience for Undergraduates" program from July through August 2002; an experiment was conducted using ventilated commercial production pails. Three worm feeding treatments (no supplemental feeding, commercial worm food, and bead filter sludge) were combined with three types of bedding ("black peat" soil alone [9.0 L; 2.4 gal]; black peat [6.0 L; 1.6 gal] plus sawdust [3.0 L; 0.8 gal]; and black peat [6.0 L; 1.6 gal] plus shredded paper [3.0 L; 0.8 gal]). Each treatment combination was assigned to a commercial production worm pail and 20.0 g (0.7 oz) (about 50 African nightcrawlers, or 70 red worms) batches of each worm species were randomly assigned to each of the nine pails. The treatment array was replicated three times on successive dates resulting in triplicate pails for each of the nine treatment combinations for each worm species (27 pails total for each species). Food treatments consisted of either 3.0 L (0.8 gal) of sludge, 29 g (1.0 oz) of commercial worm food followed by 3.0 L (0.8 gal) of recycle aquaculture system water, or no food followed by 3.0 L (0.8 gal) of recycle aquaculture system water. The amount of commercial food fed to the worms (29 g; 1.0 oz) approximated the equivalent dried solids in 3.0 L (0.8 gal) of biosolids sludge. Growth and survival in each pail was evaluated at two and four weeks.

Yellow perch recycle aquaculture system bead filter backwash sludge was found to be a suitable feedstock for both "cultured" nightcrawlers and red worms. Buckets of nightcrawlers fed bead filter sludge increased 489% in overall mass with a 96% survival after four weeks. After four weeks, the weight of red worms fed bead filter sludge increased 224% with 73% survival. Between the second and fourth week several buckets of both sludge fed and commercial food fed red worms experienced some mortality.

In this experiment, recycle aquaculture system sludge as a worm feedstock was as successful as, or outperformed the commercial worm food. After four weeks, the weight of nightcrawlers fed commercial worm food increased 415% with a 99.8% survival. Red worms fed commercial worm food had a 63% survival rate and a worm biomass increase of 187% after four weeks. The fed worms grew much better than the worms without supplemental feeding; at four weeks unfed nightcrawlers increased only 154% with 100% survival and red worms increased 127% with 97% survival. All substrate types tested were successful in maintaining worm cultures. No differences in worm growth and survival could be attributed to the various substrates. However, preliminary results suggest that the addition of sawdust allows better drainage and drying of the bedding. Addition of sawdust would probably reduce the labor costs required for separation and picking of the worms from the substrate at harvest.

Samples of worms, bedding substances, and composts from both the continuous compost bins and the sludge feeding experiment were freeze-dried for isotope and carbon analysis: nitrogen ratio to characterize the alteration in the biosolids during the vermicomposting process. Preliminary results indicate that the freeze-dried sludge has a nitrogen content of 5.0–5.7 % nitrogen and a carbon to nitrogen ratio (C:N) of 5:1. The freeze dried compost has a nitrogen content of 2–3% and a C:N ratio of 14–15:1.

OBJECTIVE 4

A conference was held on October 9, 2003 in Ames, Iowa on the USEPA "Draft Guidance for Aquatic Animal Production Facilities to Assist in Reducing the Discharge of Pollutants" and BMPs. There were eight presentations, including two case studies of state hatchery effluent issues (Michigan and Pennsylvania), an overview of USEPA's proposed guidelines and standards, presentations on BMPs for ponds, raceways, recycle systems, and a Hazard Analysis Critical Control Points approach to prevent spread of aquatic nuisance species.

WORK PLANNED

OBJECTIVE 1

ISU researchers finished data collection at the Ehler Enterprises fish farm in August 2003, therefore, work in the last (third) year will focus on data analysis, writing the final report, and preparation of manuscripts for professional journals. The database consists of measurements of TSS, TN, TP, BOD, and other parameters. The results for Objective 1 will focus on mass balance of nutrient inputs and outputs, and evaluation of the role of the septic tank in effluent quality.

OBJECTIVE 2

In the last year, ISU researchers will be doing data analysis to compare solids removal by the triple standpipe with the drum filter components of the culture system. Following that, the final report will be prepared and also manuscripts prepared for professional journals. Talks will be prepared for regional and national aquaculture conferences.

In Year 3 UW-Madison researchers will test several filter types in the large-scale (150 and 1,500 Lpm; 40 and 396 gpm) filter boxes, and gather data including flow rates and filter capacity using effluent from commercial scale raceways.

OBJECTIVE 3

In Year 3 of the project, UW-Milwaukee researchers will conduct a trial to evaluate the acceptability of worms produced from recycle aquaculture system biosolids sludge as fish food and compare the chemical content of the fish before and after being fed worms. Red worms and cultured nightcrawlers raised on sludge are currently being periodically harvested from the continuous vermicomposting bins and frozen in small batches to support this investigation.

Isotope analyses and C:N ratios will be used to determine if there are any alterations in the biosolids during the vermicomposting process.

OBJECTIVE 4

Additional information will be generated that addresses BMPs for waste control.

IMPACTS

OBJECTIVE 1

ISU researchers are describing nutrient (nitrogen and phosphorus) inputs in water and feed, and nutrient and solids outputs in the effluent of a commercial recycle aquaculture facility that employs a septic tank to capture solids and nutrients from the effluent of the culture system. By using the septic tank and drainage field as recommended by the ISU researchers, there is zero discharge of any fish hatchery effluent to surface water. In addition, a market has been found for the dried fish sludge providing some economic return for the addition of the septic tank. The system may serve as a model for a best management strategy for waste management for an intensive, closed-system commercial aquaculture facility.

OBJECTIVE 2

ISU research has demonstrated design features of a recycle aquaculture system that rapidly removes solids as well as reduces initial facility costs. The Ehler Enterprise culture system uses dual-drain tanks that allow the operator to set the proportion of flow from the culture tank to sidewall and center drains. Because most (79%) of the flow from the culture tanks leaves the system via the sidewall drain, the size and cost of the drum filter, a major capital cost, is reduced. In addition, the findings demonstrate that the triple standpipe reduces the load of solids to the drum filter as well as facilitating rapid solids removal. Efficient solids capture and disposal is important to operating efficiency of the recycle aquaculture system, water quality for the cultured fish, and waste management.

UW-Madison will test the hypothesis that a filtration system using natural fiber filters will greatly reduce the amount and concentration of organic solids that are discharged into the environment from aquaculture raceways and ponds. The retention of solids by these filters will significantly reduce the amount of nutrients entering the receiving stream, resulting in improved water quality downstream from existing fish culture facilities.

OBJECTIVE 3

UW-Milwaukee scientists have demonstrated that fish waste sludge equivalent to approximately 35% of the weight of the food used to produce perch in recirculating systems is potentially a viable feedstock for worm culture. This can be beneficial to aquaculture, especially recycle aquaculture systems, because vermicomposting can potentially decrease the amount of waste released by converting it to salable worms and organic compost to defray some of the high operating expense of recycle aquaculture system rearing.

These investigations are still incomplete and UW-Milwaukee researchers are unaware of any applications of this technique for aquaculture waste recovery in the region.

However, in discussions with several Wisconsin recirculating system operators at the state aquaculture conference, several expressed interest in vermicomposting on a trial basis.

OBJECTIVE 4

The goal of the research in Objectives 1, 2, and 3 is to provide options for waste management and use of wastes as a valuable by-product feedstuff for worm culture. Results from those activities and findings from other studies will provide commercial operators with information on environmental regulations and the best available technologies needed to meet those regulations.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Wastes/Effluents activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-02	$80,766	$58,752	$299,980	$21,060		$379,792	$460,558
2002-03	$68,514	$59,059	$123,434	$21,918		$204,411	$272,925
TOTAL	$149,280	$117,811	$423,414	$42,978		$584,203	$733,483

NATIONAL AQUACULTURE EXTENSION CONFERENCE[8]

Project Termination Report for the Period
November 1, 2002 to October 31, 2003

NCRAC FUNDING LEVEL: $4,500 (November 1, 2002 to October 31, 2003)

PARTICIPANT:

Kevin M. Fitzsimmons	University of Arizona	Arizona
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Merle Jensen	University of Arizona	Arizona
James Murray	NOAA National Sea Grant College Program	Washington, D.C.
Maxwell H. Mayeaux	USDA Cooperative State Research, Education, and Extension Service	Washington, D.C.
James P. McVey	NOAA National Sea Grant College Program	Maryland

REASON FOR TERMINATION

The project objectives were completed.

PROJECT OBJECTIVES

(1) Learn successful approaches to problem-solving through case studies that can be replicated in other states.

(2) Demonstrate and conduct hands-on experience with state-of-the-art computer applications for improving delivery of extension programs.

(3) Identify national extension priorities and critical issues with development of corresponding action plans for implementation.

(4) Identify potential interregional extension projects, such as curriculum development or national decision-support databases.

[8]NCRAC has provided funding along with the four other Regional Aquaculture Centers for three national aquaculture extension meetings; the first was called a National Aquaculture Extension Workshop whereas the second and third were called National Aquaculture Extension Conferences. This termination report is for the third meeting which was held April 7-11, 2003 in Tucson, Arizona.

(5) Share educational materials and programs in addition to expertise.

(6) Strengthen regional and national communication networks to improve services to clientele.

(7) Develop international linkages with extension professionals in Mexico and Canada.

(8) Examine successful extension components and outcomes to research projects and develop approaches to improve integration nationwide.

(9) Develop a collective strategy to define extension's role in measuring impacts of Regional Aquaculture Center projects and collaboration with others in academia and the private sector.

(10) Improve business management skills related to aquaculture and enhance knowledge concerning marketing of aquatic products.

(11) Develop a method to evaluate the impact and accomplishments associated with the conference after six months.

PRINCIPAL ACCOMPLISHMENTS

The Third National Aquaculture Extension Conference was organized by a National Steering Committee comprised of representatives from each of the Regional Aquaculture Centers and the National Office of Sea Grant. The 4-day event was held in April 2003 in Tucson, Arizona and was hosted by the Western Regional Aquaculture Center and the University of Arizona.

A Web site was developed that was used to organize the conference and now hosts copies of some of the oral presentations and all of the abstracts (http://ag.arizona.edu/azaqua/extension/National/extensionconf.html). Despite the terrible economic conditions facing many universities and extension offices, over 100 aquaculture extension professionals attended the conference. Individual presentations addressed many of the project objectives listed above during the first two days. The third day was devoted to several hands-on workshops and presentations on aquaculture pathology, computer applications, advances in pond culture, recirculating systems, and aquaculture in the classroom. Discussion sections and social events contributed to furthering the objectives. The fourth day consisted of three separate tours to various aquaculture locations across Arizona. One tour looked at marine shrimp farms and reuse of effluents. Another tour visited freshwater farms at the University of Arizona's demonstration farm and the Gila River Community Reservation and examined their integrated aquaculture/agriculture projects. The third tour visited the Sonora Desert Museum including their aquatic displays of native fishes and ecosystems and the Biosphere 2 project to see the recirculating marine systems and the fish culture used in the project.

A CD-ROM product developed from the PowerPoint presentations was also distributed at the National Association of County Agricultural Agents meeting in July 2003. The conference Web site also continues to receive hits and downloads of presentations.

IMPACTS

The Third National Aquaculture Extension Conference provided:

- A national forum for aquaculture extension professionals to meet and discuss the issues affecting the aquaculture industry as it continues to grow.
- Up-to-date information regarding new regulations impacting the industry.
- A forum for discussion of environmental issues that extension agents and specialists must deal with as they bring

stakeholders together to solve conflicts.
- Training and experience with new technologies to improve communication and presentation skills.
- A forum for Land Grant and Sea Grant supported personnel to discuss similarities and differences in their respective programs and the issues they confront.
- Exposure to programs using aquaculture in the classroom to provide basic information on aquaculture and resource management.
- Opportunities to develop networks of contacts across the country in various aspects of aquaculture.
- Presentations and discussions regarding the role, opportunities, and issues involved with international extension.
- Training in subject matter that agents and specialists need to better manage the projects and problems they face with their clientele.
- On-site visits to farms and research projects that could provide valuable information and insights into issues aquaculture extension personnel may face in their own fields.
- Personalized instruction in pathology, computer applications, recirculating systems, aquaculture education programs, and pond culture techniques.
- An electronic compilation of extension documents in Spanish that the agents and specialists could take home and customize if needed.
- An electronic compilation of all of the abstracts and PowerPoint presentations.
- A series of poster presentations that provided additional background materials. Many of these posters were also included on the CD-ROM of conference materials.
- The end-of-conference survey determined that the conference received high marks for the presentations, social events, and tours. The workshops received generally high marks, with the exception of the recirculation workshop which the participants felt did not present much in the way of new information or equipment.

RECOMMENDED FOLLOW-UP ACTIVITIES

A post-conference evaluation survey will be mailed to the participants in October 2003 to determine how the conference has impacted their actions and their activities with clientele. The participants reported in an end-of-conference survey that they felt the conference was very worthwhile and should be held again in the future. A five-year window was the most commonly selected time frame.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded National Aquaculture Extension Workshops/Conferences.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL[a]	OTHER	TOTAL	
2002-03	$4,500	$6,218	$4,500	$38,000		$48,718	$53,218
TOTAL	$4,500	$6,218	$4,500	$38,000		$48,718	$53,218

[a]Each of the four other Regional Aquaculture Centers contributed $4,500 to the conference and $20,000 was contributed by NOAA's National Sea Grant College Program.

PERCIS III—THE 3RD INTERNATIONAL PERCID FISH SYMPOSIUM[9]

Project Termination Report for the Period
November 1, 2002 to October 31, 2003

NCRAC FUNDING LEVEL: $4,000 (November 1, 2002 to October 31, 2003)

PARTICIPANT:

Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
International Steering Committee:		
Terence Barry	University of Wisconsin-Madison	Wisconsin
Ted R. Batterson	Michigan State University	Michigan
Peter Colby	Ontario Ministry of Natural Resources	Canada
Konrad Dabrowski	Ohio State University	Ohio
Jeffrey L. Gunderson	University of Minnesota-Duluth	Minnesota
Patrick Kestemont	University of Namur	Belgium
Hannu Lehtonen	University of Helsinki	Finland
Victor Mikheev	Severtsov Institute of Ecology and Evolution	Russia
Don Pereira	Minnesota Department of Natural Resources	Minnesota
Ed Roseman	Dominion Nuclear Connecticut	Connecticut

REASON FOR TERMINATION
The project objective was completed.

PROJECT OBJECTIVE
Co-sponsor the Percis III International Percid Fish Symposium, held in Madison, Wisconsin, July 20-24, 2003.

PRINCIPAL ACCOMPLISHMENTS
Percis III was held July 20-24, 2003, at the Monona Terrace Convention Center in Madison, Wisconsin. Percis III was the successor to two previous symposia, Percis I in Ontario, Canada in 1976, and Percis II in Vaasa, Finland, in 1995. Percis III was an unqualified success; the symposium included more than 180 presentations, given by over 150 registered participants from 30 countries around the world. Percis III had almost two full days of presentations that were focused on aquaculture. In addition, the poster session contained numerous aquaculture presentations.

IMPACTS
The primary impact of Percis III was to continue to insure communication and information exchange between scientists working around the world on percid aquaculture. Meetings such as Percis III foster collaborative research and extension efforts, which will clearly enhance the development of percid aquaculture technology, and promote the development of commercial fish production. After Percis III, a summary of the current status of percid fish aquaculture was prepared by Jeffrey Malison and Robert Summerfelt, both long-

[9]NCRAC has funded one Percis project. This termination report is for the first Percis project which was chaired by Jeffrey A. Malison. It was a 1-year project that began November 1, 2002.

time NCRAC participants, and Patrick Kestemont of the University of Namur, Belgium. This summary is as follows:

> For many years, the exclusive focus of percid aquaculture had been on the production of walleye (in North America) and pikeperch (in Europe) fingerlings for stocking into natural and impounded waterways. This production continues today. These fingerlings are produced largely by public fish hatcheries, although some commercial culture has begun. The original culture method used was extensive pond culture, and although this method is still widely practiced today, the development of formulated feeds that were nutritionally adequate for walleye fingerlings permitted the use of a tandem method of extensive pond culture followed by intensive tank culture for producing fingerlings to an advanced size (e.g., 100–200 mm; 3.9–7.9 in). More recently, advances in larval diets and system engineering (e.g., methods to facilitate gas bladder inflation) have led to the development of methods for raising walleye fingerlings entirely in tanks.
>
> Since the early 1980s in the U.S., and the early 1990s in Europe, a great interest has developed in the commercial culture of yellow perch, and walleye, and Eurasian perch and pikeperch, respectively, as food fish, driven by ever-increasing demand and declining supplies from the wild. In the U.S., since 1990 a significant number of farms have attempted the commercial culture of yellow perch as food fish, and a smaller number have attempted raising walleye to food size. Some of these businesses failed, others remain in production, and new start-up efforts continue. In Europe, at least one commercial pond-based operation for Eurasian perch exists in Ireland, and several initiatives have emerged in recirculation systems and lake-based cages. At Percis III it became clear that interest is growing in the commercial culture of these species in France, Switzerland, Norway, Sweden, and Denmark.
>
> Presently, pond culture or tandem pond/tank culture are the most cost-effective methods for producing yellow perch and walleye fingerlings. Pond culture and recirculation systems appear to be the two most feasible grow-out methods for both species. Recirculation systems offer the benefit of year-round growth, in which yellow perch can be raised from hatch to market size (0.25–0.33 kg; 0.55–0.73 lb) in 12 months, walleye (0.5– 0.75 kg; 1.10–1.65 lb) in 18 months, and pikeperch (2.0 kg; 4.4 lb) in 24 months. Ponds or other systems at ambient temperature may prove more cost effective than recirculation systems, however, despite comparatively slower fish growth rates. In the U.S., a primary need (which is currently being addressed for yellow perch, but not for walleye) is the documentation of production costs for specific system types. Bio-economic data is also needed for the grow out of Eurasian perch and pikeperch. One significant problem that has developed in the U.S. and is currently restricting the development of yellow perch and walleye aquaculture is an illegal practice of mis-labeling wild-harvest juvenile pikeperch, walleye, or sauger fillets as yellow or "lake" perch. These fish are being sold at extremely low prices, and clearly this practice must be halted if the development of commercial percid aquaculture is to continue.

For all of these percid species, the commercial culture of food fish is constrained by economics. Production systems must be developed that can compete with the cost of fish harvested from the wild. Over time, one can reasonably assume that increasing demand and declining supplies will lead to higher costs, making commercial aquaculture more feasible (as is the case with most other wild-harvest seafood products). At the same time, research is needed to develop more efficient production methods and systems.

Both yellow perch and Eurasian perch are marketed at a relatively small size, compared to most other cultured fish species. Accordingly, more fingerlings are needed per unit weight of marketable food, and fingerling costs represent a very high percentage of total production costs for these species. Both of these species also grow slower than most other commercially cultured food fish. Because of these facts, methods to reduce fingerling production costs and improve growth rates are two of the highest priority research areas. For pikeperch, additional major constraints are the high variability in egg and larval quality and the sudden (stress related?) mortalities that occur during grow out.

Because of the similar biology of yellow perch, Eurasian perch, walleye, and pikeperch, advances in aquaculture technology may be applicable across all four species. In this regard, one of the primary values of Percis III was to bring scientists from around the world together to discuss their related research on these different species. Advances in various disciplines, including genetics, nutrition, physiology, endocrinology, and engineering, were described. Specific important advances included: optimization of environmental conditions, better and more cost-effective diets, the use of hybridization to improve growth, methods of controlling reproduction and spawning (including the production of fast-growing monosex female and sterile strains), and beginning efforts at producing domesticated strains for aquaculture. Efforts along all of these lines should continue, but in particular efforts aimed at improving the domestication of these species may be the most important.

RECOMMENDED FOLLOW-UP ACTIVITIES

Because of the clear importance of these fishes, and the strong interest expressed, preliminary talks have already begun regarding a Percis IV symposium, to be held perhaps in 2009 or 2010. If possible, NCRAC should support efforts at the development of such a conference.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

There were 34 aquaculture-related presentations at Percis III, many of which included results of NCRAC-funded projects, as well as a published proceedings. See the Appendix for the complete citation for the proceedings.

SUPPORT

YEAR	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2002-03	$4,000	$1,500		$9,000	$17,400	$27,900	$31,900
TOTAL	$4,000	$1,500		$9,000	$17,400	$27,900	$31,900

APPENDIX

EXTENSION

NCRAC Extension Fact Sheet Series

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. NCRAC Fact Sheet Series #101, NCRAC Publications Office, Iowa State University, Ames.

Harding, L.M., C.P. Clouse, R.C. Summerfelt, and J.E. Morris. 1992. Pond culture of walleye fingerlings. NCRAC Fact Sheet Series #102, NCRAC Publications Office, Iowa State University, Ames.

Kohler, S.T., and D.A. Selock. 1992. Choosing an organizational structure for your aquaculture business. NCRAC Fact Sheet Series #103, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Transportation of fish in bags. NCRAC Fact Sheet Series #104, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Use and application of salt in aquaculture. NCRAC Fact Sheet Series #105, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. 1993. Pond culture of channel catfish in the North Central Region. NCRAC Fact Sheet Series #106, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., C.C. Kohler, and C.C. Mischke. 1999. Pond culture of hybrid striped bass in the North Central Region. NCRAC Fact Sheet Series #107, NCRAC Publications Office, Iowa State University, Ames.

Cain, K., and D.Garling. 1993. Trout culture in the North Central Region. NCRAC Fact Sheet Series #108, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1999. Marketing seafood to restaurants in the North Central Region. NCRAC Fact Sheet Series #110, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1997. Costs for pond production of yellow perch in the North Central Region, 1994-95. NCRAC Fact Sheet Series #111, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1999. Supermarkets and seafood in the North Central Region. NCRAC Fact Sheet Series #112, NCRAC Publications Office, Iowa State University, Ames.

Garling, D. In press. Whirling disease. NCRAC Fact Sheet Series #113, NCRAC Publications Office, Iowa State University, Ames.

Garling, D., and M. Riche. 2003. Feeding tilapia in intensive recirculating systems. NCRAC Fact Sheet Series #114, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Technical Bulletin Series

Thomas, S.K., R.M. Sullivan, R.L Vertrees, and D.W. Floyd. 1992. Aquaculture law in the north central states: a digest of state statutes pertaining to the production and marketing of aquacultural products. NCRAC Technical Bulletin Series #101, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. A basic overview of aquaculture: history, water quality, types of aquaculture, production methods. NCRAC Technical Bulletin Series #102, NCRAC Publications Office, Iowa State University, Ames.

Kinnunen, R.E. 1992. North Central Region 1990 salmonid egg and fingerling purchases, production, and sales. NCRAC Technical Bulletin Series #103, NCRAC Publications Office, Iowa State University, Ames.

Hushak, L.J., C.F. Cole, and D.P. Gleckler. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central Region. NCRAC Technical Bulletin Series #104, NCRAC Publications Office, Iowa State University, Ames.

Meronek, T., F. Copes, and D. Coble. 1998. The bait industry in Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin. NCRAC Technical Bulletin Series #105, NCRAC Publications Office, Iowa State University, Ames.

Lichtkoppler, F.P. 1993. Factors to consider in establishing a successful aquaculture business in the North Central Region. NCRAC Technical

Bulletin Series #106, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., and J. R. Riepe. 1994. Niche marketing your aquaculture products. NCRAC Technical Bulletin Series #107, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., J. Morris, and D. Selock. 1994. Cage culture of fish in the North Central Region. NCRAC Technical Bulletin Series #110, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1997. Enterprise budgets for yellow perch production in cages and ponds in the North Central Region, 1994/95. NCRAC Technical Bulletin Series #111, NCRAC Publications Office, Iowa State University, Ames.

Brown, P., and J. Gunderson, editors. 1997. Culture potential of selected crayfishes in the North Central Region. NCRAC Technical Bulletin Series #112, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1998. Walleye markets in the North Central Region: results of a 1996/97 survey. NCRAC Technical Bulletin Series #113, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., and C.C. Mischke. 1999. Plankton management for fish culture ponds. NCRAC Technical Bulletin Series #114 NCRAC Publications Office, Iowa State University, Ames.

Lane, R.L., and J.E. Morris. 2000. Biology, prevention, and effects of common grubs (Digenetic trematodes) in freshwater fish. NCRAC Technical Bulletin Series #115, NCRAC Publications Office, Iowa State University, Ames.

Ramseyer, L.J., and D. Garling. In review. Fish nutrition and aquaculture waste management. NCRAC Technical Bulletin Series #116, NCRAC Publications Office, Iowa State University, Ames.

Daily, S., Selock, D., and Kohler, S. 2002. Fish-farm business plan workbook. NCRAC Technical Bulletin Series #117, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Video Series

Swann, L. 1992. Something fishy: hybrid striped bass in cages. VHS format, 12 min. NCRAC Video Series #101, NCRAC Publications Office, Iowa State University, Ames.

Pierce, R., R. Henderson, and K. Neils. Aquacultural marketing: a practical guide for fish producers. 1995. VHS format, 19 min. NCRAC Video Series #102, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., editor. 1993. Investing in freshwater aquaculture. VHS format, 120 min. NCRAC Video Series #103, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., and C.C. Mischke. 1998. Sunfish (*Lepomis* spp.) culture. NCRAC Video Series #104, NCRAC Publications Office, Iowa State University, Ames.

Ingham, S. 1999. A guide to making safe smoked fish. NCRAC Video Series #105, NCRAC Publications Office, Iowa State University, Ames.

Swenson, W. 2000. Fish farming: some industry perspectives. NCRAC Video Series #106, NCRAC Publications Office, Iowa State University, Ames.

Ingham, S. 2000. Fish processing plant sanitation. NCRAC Video Series #107, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Culture Series

Summerfelt, R., editor. 1996. Walleye culture manual. NCRAC Culture Series #101, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., C.C. Mischke, and D.L. Garling, editors. 2003. Sunfish culture guide. NCRAC Culture Series #102, NCRAC Publications Office, Iowa State University, Ames.

Garling, D.L. In preparation. Yellow perch culture guide. NCRAC Culture Series #103, NCRAC Publications Office, Iowa State University, Ames.

Other Videos

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part I). VHS format, 38 min. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part II). VHS format, 41 min. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

CD-ROMs

Swann, L. 1998. Getting started in freshwater aquaculture. NCRAC CD-ROM Series #101, NCRAC Publications Office, Iowa State University, Ames.

Kinnunen, R. 2002. Environmental Strategies for Aquaculture Symposium proceedings. NCRAC CD-ROM Series #102, NCRAC Publications Office, Iowa State University, Ames.

Boylan, J., and J. Morris. In press. Invertebrate identification for fish culturists. NCRAC CD-ROM Series #103, NCRAC Publications Office, Iowa State University, Ames.

Situation and Outlook Report

Hushak, L.J. 1993. North Central Regional aquaculture industry situation and outlook report, volume 1 (revised October 1993). NCRAC Publications Office, Iowa State University, Ames.

Other Publications in Print

Myers, J.J., and R.A. Pierce. 2000. Missouri aquaculture directory. Missouri Department of Agriculture, Jefferson City, Missouri.

Pierce, R.A., and C. Hicks. 2000. Understanding aquaculture businesses and their financial needs. Pages 75-76 *in* R. Plain, editor. Missouri farm financial outlook 2001. University Outreach and Extension, Department of Agricultural Economics, University of Missouri-Columbia.

Swann, D.L., and M.E. Einstein. 2000. User analysis and future directions of the web-based Aquaculture Network Information Center. Journal of Extension 38(5).

Workshops and Conferences

Salmonid Culture, East Lansing, Michigan, March 23-24, 1990. (Donald L. Garling)

Midwest Regional Cage Fish Culture Workshop, Jasper, Indiana, August 24-25, 1990. (LaDon Swann)

Aquaculture Leader Training for Great Lakes Sea Grant Extension Agents, Manitowoc, Wisconsin, October 23, 1990. (David J. Landkamer and LaDon Swann)

Regional Workshop of Commercial Fish Culture Using Water Reuse Systems, Normal, Illinois, November 2-3, 1990. (LaDon Swann)

First North Central Regional Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. (Donald L. Garling, Lead; David J. Landkamer, Joseph E. Morris and Ronald Kinnunen, Steering Committee)

Crayfish Symposium, Carbondale, Illinois, March 23-24, 1991. (Daniel A. Selock and Christopher C. Kohler)

Fish Transportation Workshops, Marion, Illinois, April 6, 1991 and West Lafayette, Indiana, April 20, 1991. (LaDon Swann and Daniel A. Selock)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 15-16, 1991. (LaDon Swann)

National Aquaculture Extension Workshop, Ferndale, Arkansas, March 3-7, 1992. (Joseph E. Morris, Steering Committee)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 19-20, 1992. (LaDon Swann)

In-Service Training for CES and Sea Grant Personnel, Gretna, Nebraska, February 9, 1993. (Terrence B. Kayes and Joseph E. Morris)

Aquaculture Leader Training, Alexandria, Minnesota, March 6, 1993. (Jeffrey L. Gunderson and Joseph E. Morris)

Investing in Freshwater Aquaculture, Satellite Videoconference, Purdue University, April 10, 1993. (LaDon Swann)

National Extension Wildlife and Fisheries Workshop, Kansas City, Missouri, April 29-May 2, 1993. (Joseph E. Morris)

Commercial Aquaculture Recirculation Systems, Piketon, Ohio, July 10, 1993. (James E. Ebeling)

Yellow Perch and Hybrid Striped Bass Aquaculture Workshop, Piketon, Ohio, July 9, 1994. (James E. Ebeling and Christopher C. Kohler)

Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994. (LaDon Swann)

Aquaculture in the Age of the Information Highway. Special session, World Aquaculture Society, San Diego, California, February 7, 1995. (LaDon Swann)

Second North Central Regional Aquaculture Conference, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson, Lead; Fred P. Binkowski, Donald L. Garling, Terrence B. Kayes, Ronald E. Kinnunen, Joseph E. Morris, and LaDon Swann, Steering Committee)

Walleye Culture Workshop, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson)

Aquaculture in the Age of the Information Highway. Multimedia session, 18 month meeting of the Sea Grant Great Lakes Network, Niagra Falls, Ontario, May 6, 1995. (LaDon Swann)

AquaNIC. Annual Meeting of the Aquaculture Association of Canada, Nanaimo, British Columbia, June 5, 1995. (LaDon Swann)

Yellow Perch Aquaculture Workshop, Spring Lake, Michigan, June 15-16, 1995. (Donald L. Garling)

Rainbow Trout Production: Indoors/Outdoors, Piketon, Ohio, July 8, 1995. (James E. Ebeling)

North Central Regional Aquaculture Center Hybrid Striped Bass Workshop, Champaign, Illinois, November 2-4, 1995. (Christoper C. Kohler, LaDon Swann, and Joseph E. Morris)

Third North Central Regional Aquaculture Conference, Indianapolis, Indiana, February 6-7, 1997. (LaDon Swann)

Overview of Sunfish Culture. Missouri Joint Aquaculture Conference, Springfield, Missouri, March 4-6, 1998. (Joseph E. Morris)

Seafood and Food Safety Issues Related to Aquaculture, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Ronald E. Kinnunen)

Overview of Sunfish Culture. North Central Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Joseph E. Morris and Charles C. Mischke)

Angel Fish Production, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (LaDon Swann)

Potential of Recirculating Systems in the North Central Region, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (LaDon Swann)

Overview of Freshwater Shrimp Culture, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Laura Tiu)

Fertilization Regimes for Fish Culture Ponds, Wisconsin Aquaculture Conference, Green Bay, Wisconsin, March 12-13, 1999. (Joseph E. Morris)

Extension Programming in the North Central Region, SERA-IEG-9, Frankfort, Kentucky, March 14-16, 1999. (Joseph E. Morris)

Description of the Aquaculture and Bait Fish Industries: Threat Evaluation and Identification of Critical Control Points, International Joint Commission Workshop on Exotic Policy, Milwaukee, Wisconsin, September 22-26, 1999. (Jeffrey L. Gunderson)

Fisheries Management in the North Central Region, 9th National Extension Wildlife, Fisheries, and Aquaculture Conference, Portland, Maine, September 29-October 2, 1999. (Joseph E. Morris, and S.K. Whitcomb)

Internet Resources for Aquaculture Education and Communications: Present and Future, 9th National Extension Wildlife, Fisheries, and Aquaculture Conference, Portland, Maine, September 29-October 2, 1999. (LaDon Swann)

"I've got this hog barn..." Workshop, Piketon, Ohio, November 12, 2002. (Laura G. Tiu)

Applications of HACCP in Aquaculture, Aquaculture America 2003, Louisville, Kentucky, February 18-21, 2003. (Ronald E. Kinnunen)

Food Safety Issues Related to Aquaculture, Aquaculture America 2003, Louisville, Kentucky, February 18-21, 2003. (Ronald E. Kinnunen)

The ANS-HACCP Approach: Reducing the Risk of Spreding Aquatic Nuisance Species, Aquaculture America 2003, Louisville, Kentucky, February 18-21, 2003. (Ronald E. Kinnunen)

Use of Natural Ponds for Fish and Baitfish Production, Aquaculture America 2003, Louisville, Kentucky, February 18-21, 2003. (Ronald E. Kinnunen)

Overviews on Production, Nutrition, Economics, and Fish Health Management for Yellow Perch, *Perca flavescens*, Aquaculture America 2003, Louisville, Kentucky, February 18-21, 2003. (Fred P. Binkowski, Ronald E. Kinnunen, and Geoffrey Wallat)

Hybrid Striped Bass Workshop, Jackson, Missouri, March 5, 2003. (Ronald E. Kinnunen and Robert A. Pierce II)

Sunfish Culture in the Midwest, Nebraska Aquaculture Annual Meeting, North Platt, Nebraska, March 29, 2003. (Joseph E. Morris)

Developing an Aquaculture Community, Nebraska Aquaculture Annual Meeting, North Platt, Nebraska, March 29, 2003. (Laura G. Tiu)

Extension Program Assessment: An Extension Specialist's View. Aquaculture Extension Conference, Tucson, Arizona, April 7-11, 2003. (Joseph E. Morris)

Great Lakes Native American Involvement in Fisheries Extension Programs, National Aquaculture Extension Conference, Tucson, Arizona, April 7-11, 2003. (Ronald E. Kinnunen and Charles Pistis)

On Farm Demonstration of Freshwater Shrimp Culture in Southern Ohio, National Aquaculture Extension Conference, Tucson, Arizona, April 7-11, 2003. (Laura G. Tiu)

Proceedings

Proceedings of the North Central Regional Aquaculture Conference. 1991. First North Central Regional Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.

Gunderson, J., editor. 1995. Proceedings of the Combined North Central and Ninth Annual Minnesota Aquaculture Conference and Tradeshow. Second North Central Regional Aquaculture Conference, Minneapolis, Minnesota, February 17-18, 1995.

Swann, L., editor. 1997. Proceedings of the 1997 North Central Regional Aquaculture Conference. Third North Central Regional Aquaculture Conference, Indianapolis, Indiana, February 6-7, 1997. Illinois-Indiana Sea Grant Program, Publication CES-305. (Also available electronically at: http://ag.ansc.purdue.edu/aquanic/publicat/state/il-in/ces-305.htm)

Morris, J.E., editor. 1999. Aquaculture at the crossroads: linking the past to the future. Compilation of abstracts, papers, and supporting articles for the Fourth North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999.

ECONOMICS/MARKETING

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Aubineau, C.M. 1996. Characterization of the supply of walleye fingerlings in the north central region of the U.S. Master's thesis. Illinois State University, Normal.

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SOME COMMONLY USED ABBREVIATIONS AND ACRONYMS

×	cross; times
ANS	aquatic nuisance species
AquaNIC	Aquaculture Network Information Center
BMPs	best management practices
BOD	Board of Directors biochemical oxygen demand
°C	degrees Celsius
CES	Cooperative Extension Service
cm	centimeter
DO	dissolved oxygen
EAA	essential amino acid
°F	degrees Fahrenheit
FPL	[USDA] Forest Products Laboratory
ft, ft^3	foot, cubic foot
g	gram(s)
gal	gallon(s)
gpm	gallons per minute
h	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis Critical Control Points
hp	horsepower
IAC	Industry Advisory Council
in	inch(es)
ISU	Illinois State University Iowa State University
kg	kilogram(s)
L	liter(s)
lb	pound(s)
LMSFH	Lake Mills State Fish Hatchery
Lpm	liters per minute
m, m^3	meter, cubic meter
µm	micrometer
mg	milligram(s)
mm	millimeter(s)
MSU	Michigan State University
N	number
NCC	National Coordinating Council
NCR	North Central Region
NCRAC	North Central Regional Aquaculture Center
NDSU	North Dakota State University
OAA	Ohio Aquaculture Association
OSU	Ohio State University
oz	ounce(s)
POW	Plan of Work
ppm	parts per million
ppt	parts per trillion
Purdue	Purdue University
RAC(s)	Regional Aquaculture Center(s)
SIUC	Southern Illinois University-Carbondale
TC	Technical Committee (TC/E = Technical Committee/ Extension; TC/R = Technical Committee/Research)
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
UMC	University of Missouri-Columbia
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
UW-Madison	University of Wisconsin-Madison
UW-Milwaukee	University of Wisconsin-Milwaukee